SCIENCE SERVICE SCIENCE PROGRAM

MAN IN SPACE

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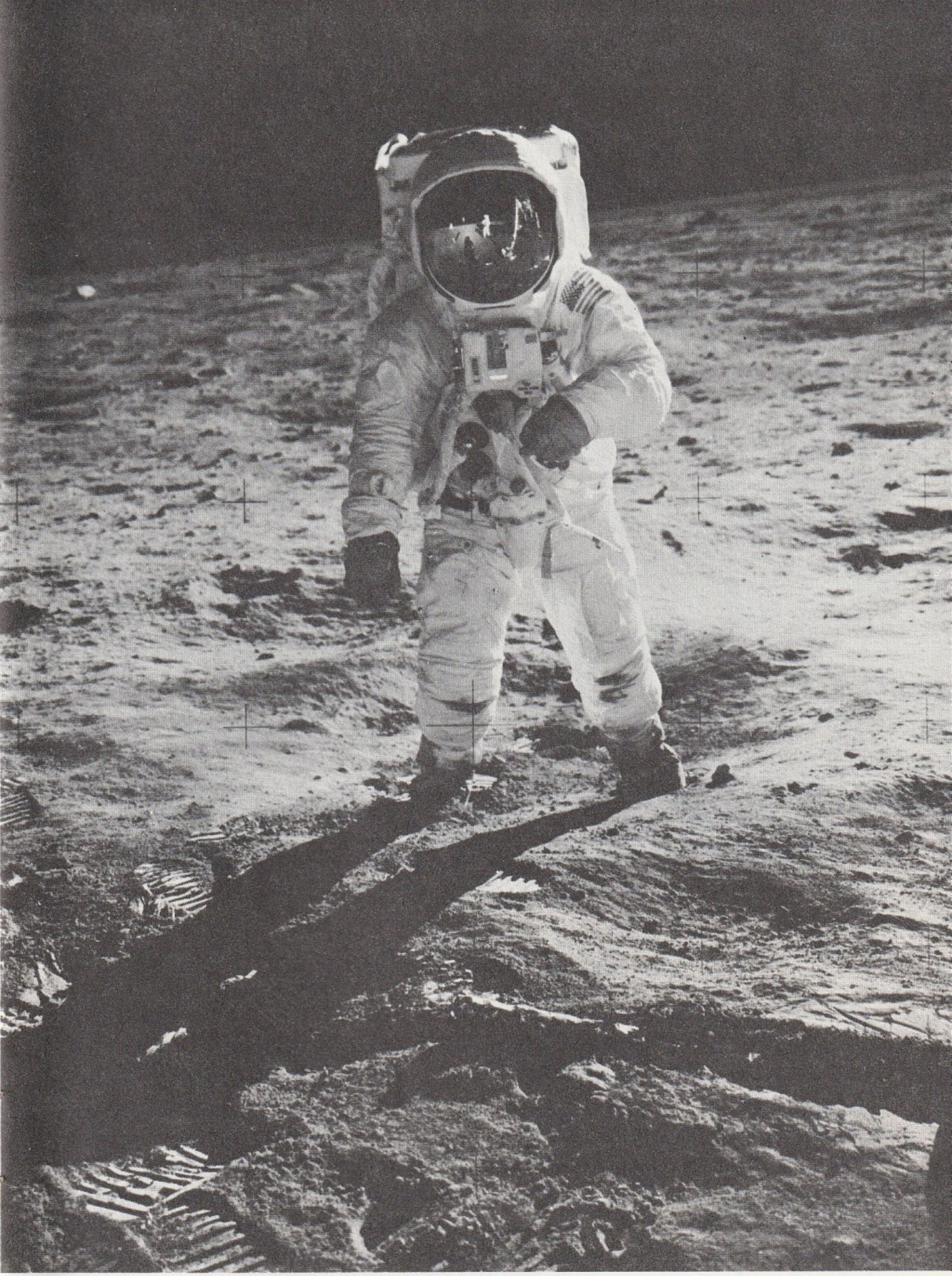


20 July, 1969—Man walks on the moon for the first time.

To the Moon—and Beyond

ALL OF US LIVING TODAY are witnesses to one of the greatest adventures of history—the exploration of outer space. Hundreds of years from now historians will be looking back, for example, to mark 20 July, 1969, as the date when man first set foot on the moon and opened the way to a vast new world.

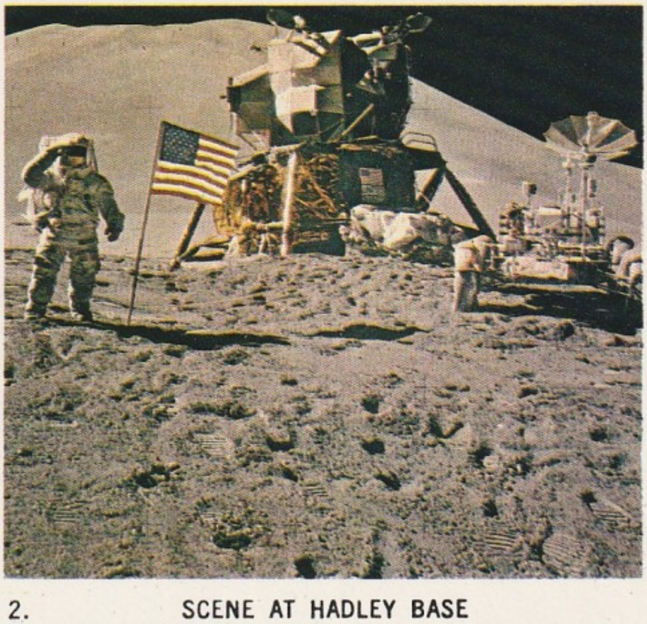
Landing men on the moon in Project Apollo was only the beginning, a first feeble step. The long-range goal is to be able to voyage confidently to the farthest limits of man's ingenuity. Scientists want to establish permanent stations in space—laboratories, observatories, testing platforms and way stations. They want colonies on the moon and they want to visit Mars and Venus.

There really is no known limit to how far man can go in space. If you could launch a spaceship to the center of the Milky Way, our own galaxy, it would take 26,000 light-years to get there—that is, 26,000 years of travel at the speed of light, or 186,000 miles a second. And the Milky Way is only one infinitesimally small corner of the universe. It gives you some idea, at least, of how vast outer space is. Yet it is this uncharted, hostile region that man, in just the past decade or so, has set out to conquer—slowly but surely.

This adventure, like all others, starts close to home. Space is waiting just ten miles from any man's front door. That is where the story begins, because ten miles straight up is the crossover zone where man learns that his earth-born body is no match for the conditions that stand between him and the exploration of the heavens.

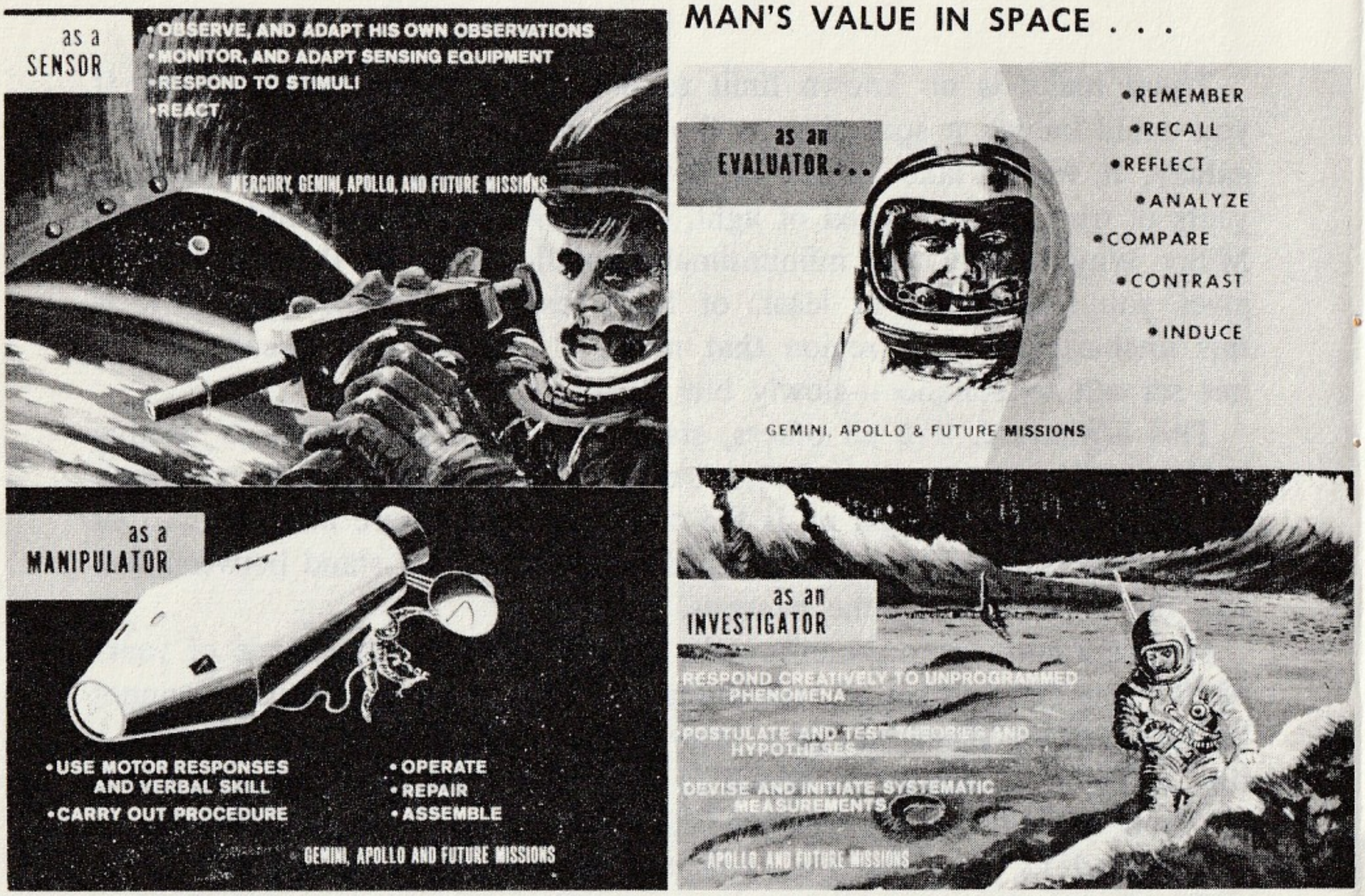
Man is a complex mechanism, the product of many thousands of years of living under one set of conditions. He can be trained, but he cannot be made over. When he goes into space, man must take with him a tiny earth, in a capsule, in which to live. This manner of living involves not only the air he breathes and the temperature and humidity he is accustomed to, but also his protection from heat, cold, weightlessness and radiation. He must be fed, he must get exercise, he must find sleep.

Trail blazers of the Space Age face problems and dangers that history's bravest venturers never knew. Some problems involve engineering, for rockets must be powerful, precise and reliable. Other problems—the ones this booklet is more concerned with—involve man himself,



Apollo 15—Lieut. Col. James B. Irwin saluting the flag he and Col. David R. Scott set up—with a rod to hold it straight in the airless environment. In the background are Falcon, the lunar lander, and the lunar rover.

2. SCENE AT HADLEY BASE

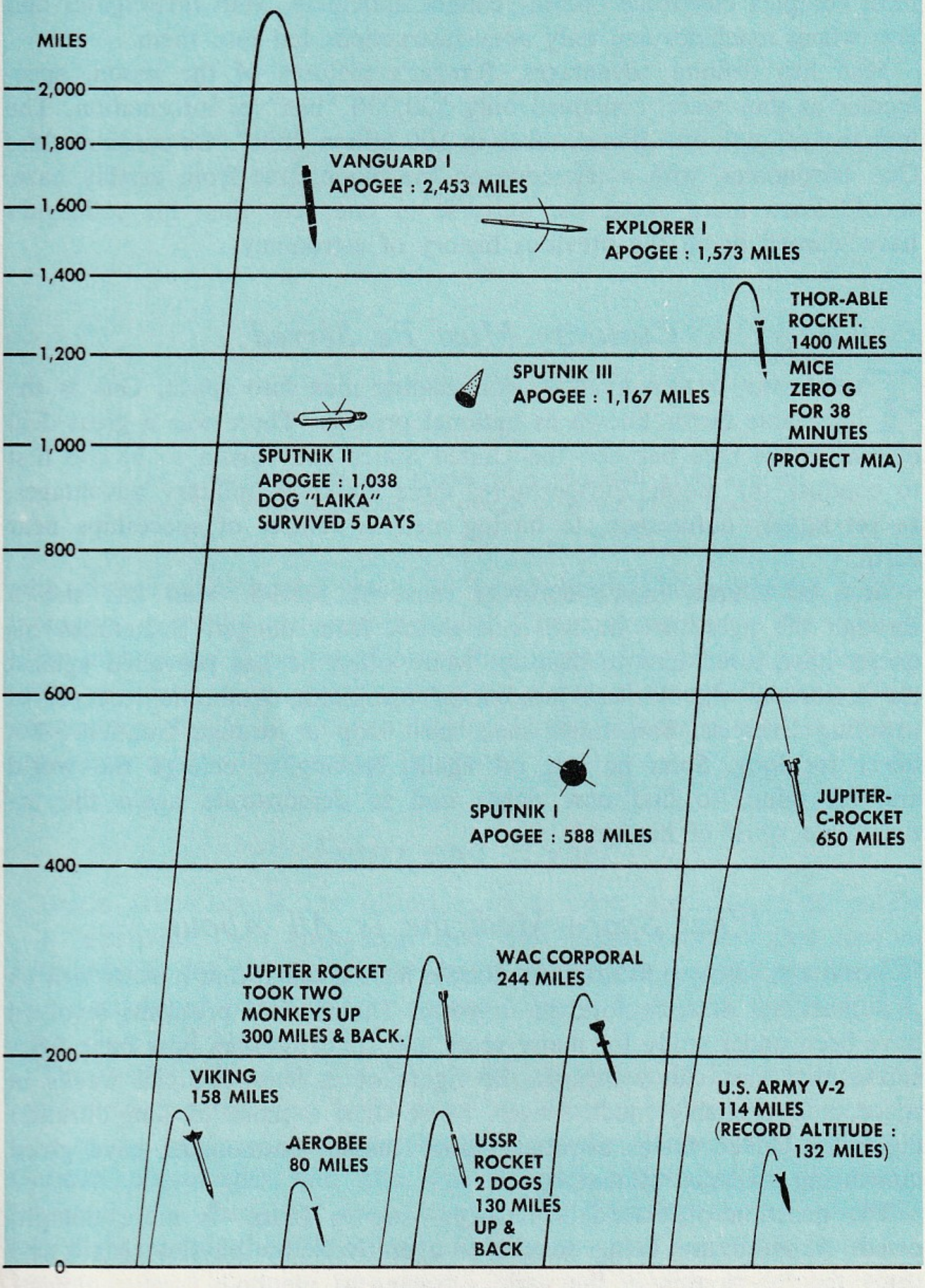


his ability not only to live in space, but to work there. The universe is truly an inhospitable environment where death may ride with the next breath; where cosmic rays or solar flares could be lethal if not protected against; where human errors—trivial on earth—could bring sudden death.

Why Go into Space?

SOME PEOPLE INSIST that the risks and expense of sending men into space are too great for the information they will bring back to earth. These people frequently ask: "Why send men into space at all? Why can't spacecraft, loaded with clever electronic gadgets and television eyes, find out all we need to know?"

There are several reasons. For one, no machine will ever replace all the functions of the human brain. In an emergency a trained mind is far superior to a string of calculators. A brain weighs about three pounds but it has 10 billion nerve cells comparable to 10 billion vacuum tubes. Man's value is to make difficult judgments in situations that the



This diagram shows altitudes reached by some of the earliest rockets and satellites. Men have since gone to the moon.

most complex electronic "brain" cannot anticipate. Man *investigates* and *acts* where machines can only *obey* instructions fed into them.

Man has definite advantages. Ranger's pictures of the moon, spectacular as they were, contained only 500,000 "bits" of information. The human eye, with one glance, takes in 100 billion "bits". Or consider this: One astronomer, with a telescope on the moon, free from earthly haze, should learn more about the universe in one year than his colleagues have learned in all the previous history of astronomy.

Curiosity Must Be Served

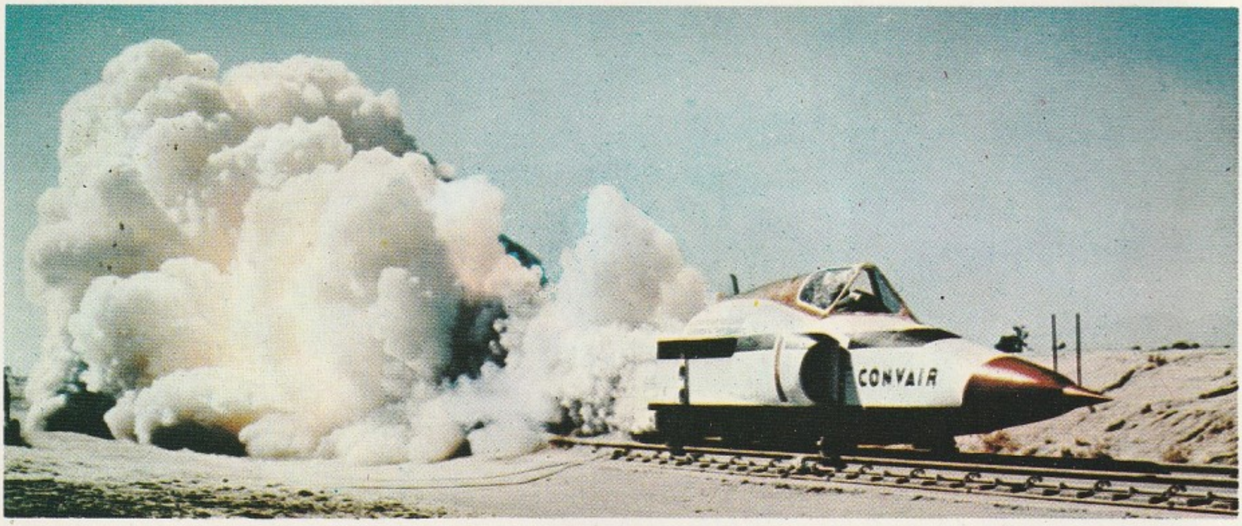
THERE ARE OTHER REASONS for sending men into space. One is the intangible factor known as national prestige. There was a great deal of that in the race between the United States and Russia to be the first to conquer the moon. Furthermore, there could be military advantages, as yet largely unforeseen, to having men in control of spaceships near earth.

And, of course, man's curiosity must be served. Man has shown through the ages that he will not shrink from danger. Sometimes his quests have lured him to disaster. More often he has prevailed against the terrors of the African jungles, of forbidding Antarctic icecaps, of towering Everests. Sometimes man must stop at strange frontiers—but never for long. Soon he sets off again, seeking to enlarge the world and his mind, to find new riches and to demonstrate again the indomitable spirit of his kind.

What Space Medicine Is All About

BOTH THE UNITED STATES and Russia have decided that men as well as machines must explore the universe. The medical problems involved have been under study for many years and space doctors now have been shown that men can withstand the rigors of at least two full weeks in space, and probably much longer. More than a score of long-duration flights by United States astronauts and Russian cosmonauts have given convincing evidence of that.

The question of extended journeys—say to Mars—is more complicated. Answers are being sought co-operatively by physiologists (who study the functioning of the various organs of the body), psychologists (whose area is men's mental welfare) and medical scientists. Working



3. ROCKET SLED UNDER FULL POWER

The Convair rocket sled comes to a standstill after a high-speed run when it reaches the trough of water which brakes it.

with them are scientists such as biophysicists, biometricians, radiobiologists, microbiologists and biologists. The common key to the work of these men is the Greek word *bios*. *Bios* means life, or living things, so these scientists are applying their great stores of knowledge and lively imaginations to life, in order to develop further safeguards against strange conditions man will encounter in space.

Faster and Higher

SPACE MEDICINE is the offspring of aviation medicine. The parent "discipline" was born soon after the Wright brothers first flew at Kitty Hawk, for as planes flew faster and higher, special studies had to be made of pilot fatigue, oxygen supply, high-dash speed effects, cold, glare and blackouts.

The British, Germans and Americans led the world in aerial medical research during the great buildups of air armadas before World War II. One of the brightest names in the field was Dr. Hubertus Strughold, a German physiologist who also was a space visionary. In his Berlin laboratory Dr. Strughold spent many hours dreaming about interplanetary flight, and at the risk of being laughed at—and sometimes he was—he went ahead planning zero-gravity tests and studies of tremendously high altitudes that had no practical application in those days.

U.S. SPACE LOG—FROM MERCURY TO THE MOON LANDINGS

U.S. MERCURY PROGRAM

Date	Mission	Crew	Duration
5 May, 1961	Mercury 3	Shepard	0 orbits— 15 minutes 22 seconds
21 July, 1961	Mercury 4	Grissom	0 orbits— 15 minutes 37 seconds
20 February, 1962	Mercury 6	Glenn	3 orbits— 4 hours 55 minutes
24 May, 1962	Mercury 7	Carpenter	3 orbits— 4 hours 56 minutes
3 October, 1962	Mercury 8	Schirra	6 orbits— 9 hours 13 minutes
15-16 May, 1963	Mercury 9	Cooper	22 orbits— 34 hours 20 minutes

U.S. GEMINI PROGRAM

Date	Mission	Crew	Duration
23 March, 1965	Gemini 3	Grissom-Young	3 orbits— 4 hours 53 minutes
3-7 June, 1965	Gemini 4	McDivitt-White	65 orbits— 97 hours 56 minutes
21-29 August, 1965	Gemini 5	Cooper-Conrad	127 orbits—190 hours 55 minutes
4-18 December, 1965	Gemini 7	Borman-Lovell	220 orbits—330 hours 36 minutes
15-16 December, 1965	Gemini 6	Schirra-Stafford	17 orbits— 25 hours 51 minutes
16 March, 1966	Gemini 8	Armstrong-Scott	7 orbits— 10 hours 42 minutes
3-6 June, 1966	Gemini 9	Stafford-Cernan	48 orbits— 72 hours 21 minutes
18-21 July, 1966	Gemini 10	Young-Collins	44 orbits— 70 hours 30 minutes
12-15 September, 1966	Gemini 11	Conrad-Gordon	44 orbits— 71 hours 17 minutes
11-15 November, 1966	Gemini 12	Lovell-Aldrin	59 orbits— 94 hours 36 minutes

U.S. APOLLO MOON LANDINGS

Date	Mission	Crew	Duration
16-24 July, 1969	Apollo 11	Armstrong-Aldrin-Collins	First moon landing—195 hours, 18 minutes
14-24 November, 1969	Apollo 12	Conrad-Bean-Gordon	Second moon landing—244 hours, 36 minutes ;
11-17 April, 1970	Apollo 13	Lovell-Haise-Swigert	Mission aborted in flight
31 January-9 February, 1971	Apollo 14	Shepard-Mitchell-Roosa	Third moon landing—216 hours, 2 minutes
26 July-7 August, 1971	Apollo 15	Scott-Irwin-Worden	Fourth moon landing—295 hours

When the war ended in 1945, many German rocket specialists brought their talents to the United States and a few aviation medical men such as Professor Strughold were among them. Once in the U.S., Dr. Strughold went to work for the Air Force and was soon recognized as one of the country's leading authorities on space flight medical problems. Together with two other Air Force doctors, he symbolized the Air Force's pioneering studies in the "human factors" of space travel. The other two were sometimes referred to as "do-it-yourself" flight surgeons because they carried out difficult and dangerous experiments on themselves. Many "old-timers" still remember the dramatic rocket-sled tests to gauge the effects of rapid accelerations, conducted by Col. John Paul Stapp, and the super-high ballooning of Lt. Col. David G. Simons. Their daring experiments were conducted long before America's first astronauts were shot from Cape Kennedy.

Where Space Begins . . .

DR. STRUGHOLD WAS FOREMOST among those who made the point that so far as man's weak and sensitive body is concerned, space doesn't begin at 600 miles above the surface of the earth (the top of the ionosphere) but at nine and one-half miles, where man is first endangered by anoxia, or lack of oxygen; where, in other words, man cannot live long without special protective encapsulation. And astrobiologists, scientists who deal with living matter in space, point out that at twelve miles up a man's body fluids would vaporize without a pressurized cabin, or pressurized space suit, just as they would farther out in space.

Twenty-five miles up there is no helpful blanket of atmosphere to give protection against primary cosmic rays. There are meteors zipping around starting at fifty miles; at sixty miles there is almost complete silence—the weird stillness of true space where the air is too thin to carry sound waves; and at eighty miles the sky appears velvet black. So space physicians contend the entire zone from ten to 120 miles is actually the equivalent of space, so far as man's body is concerned, and space phenomena in their entirety start at 120 miles.

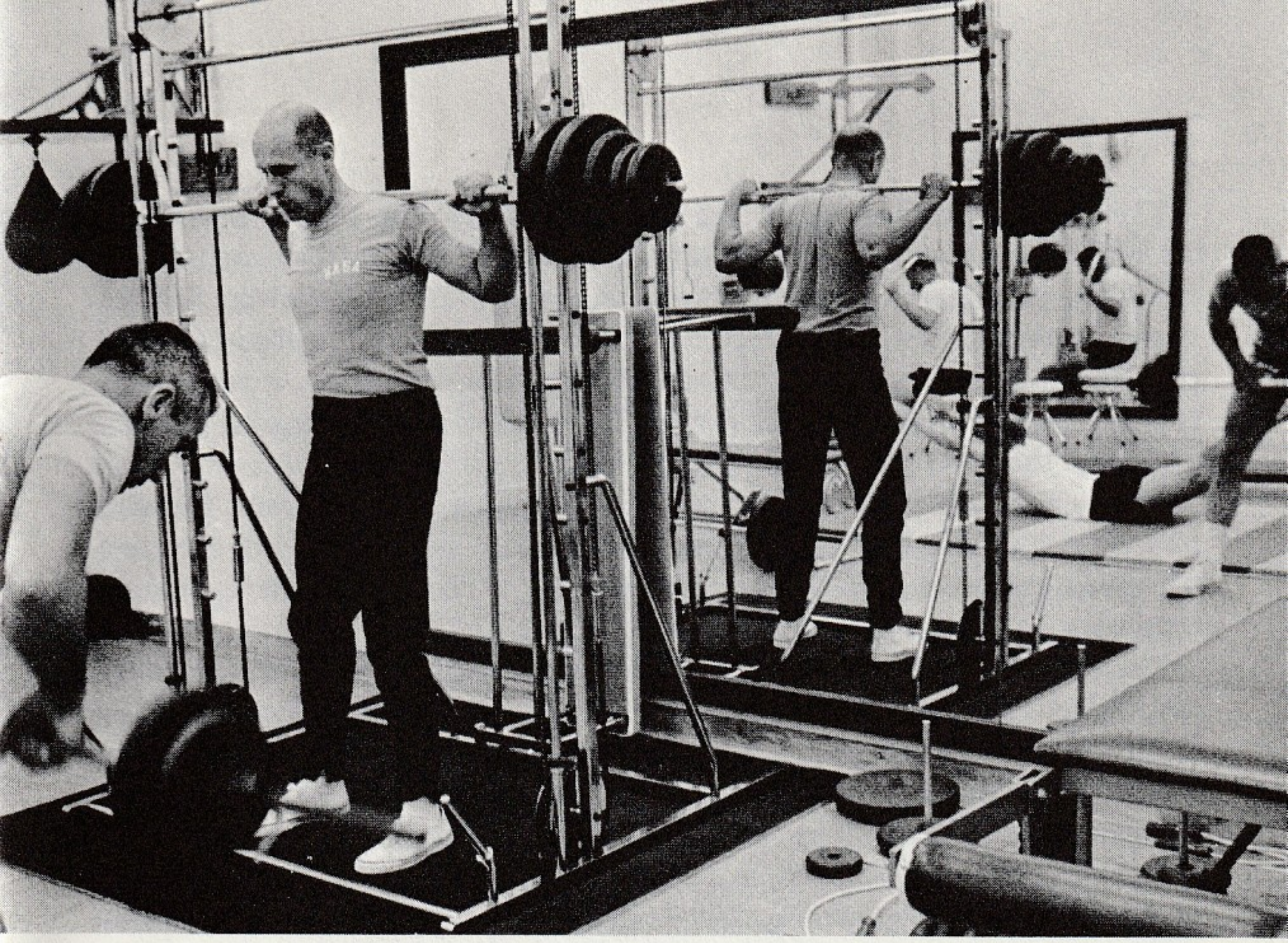
What Makes an Astronaut?

IT WAS ON THE BASIS of painstaking research by the first space doctors that the National Aeronautics and Space Administration was

able to set up the qualifications and then select the first astronauts. When the selection boards met they were looking for true astronautic pioneers—not only men to orbit the earth but men mentally and physically equipped to make even more demanding journeys. It is a long haul to the moon—221,500 miles at its closest point. And one day NASA may start looking beyond the moon to trips of greater daring. Future generations of astronauts will be called on to make those trips, for our present spacemen will be too old when the time comes to travel beyond the moon. But the requirements are going to be similar, and the selections just as difficult to make. Yet who knows—the kind of future spaceman we are talking about may be reading these words right now.

Choosing the Right Men

A LOT OF SCIENTIFIC THEORY has been advanced about what makes a good spaceman. Because of the unusual psychological hazards involved, serious suggestions were made at first that "unsophisticated" Eskimos or "other-worldly" Buddhist monks might make the best crew members—mentally speaking, that is. Or midgets because they would take up less room. One researcher even nominated people with schiz-



Astronauts keeping in shape at the gym.

ophrenia, a mental disorder, because he felt that anyone who wants to fly off into space must be a strange bird, indeed.

When it came right down to selecting America's astronauts—and from all appearances it was the same in Russia—the facts were different. America's spacemen are intelligent, adventurous but serious men, with very special qualifications.

Thousands of men have applied for astronaut training—not many more than seventy have been accepted. The screening is rigid.

Passing the Test

SUPPOSE YOU HAVE the qualifications necessary to be an astronaut and get right down to the final weeding-out process, the physical exam. Here is an idea of what you might go through, as taken from an actual account by Edward A. Herron of the procedure at the School of Aerospace Medicine at Brooks Air Force Base in Texas.

The candidates show up in the uniforms of the Air Force, the Navy, the Marines. There are a few civilians. All of them are the lean, spare, jet-fighter pilot types. Dr. Lawrence E. Lamb, Aerospace Medical Science Division chief at Brooks, greets the men: "You will undergo rigorous physical testing," he says. "It will be tedious, some of it annoying, some of it downright uncomfortable. We submit our findings to NASA, and it is they who make the final determination. Good luck."

Each candidate is then assigned to one of ten physicians who, in turn, interview him in detail on his past medical history. A rigid schedule of appointments is worked out, exactly like those of a college student preparing for a semester's activity.

The minute-by-minute and inch-by-inch testing that seeks to determine any hidden medical deficiency is, in Mr. Herron's words, "awesome in its thoroughness." Dr. James Culver, chief of ophthalmology, says: "We are interested in tests that will help us predict not only how well each astronaut will perform but how long the nation can expect peak performance from each candidate. There is much at stake. A great deal of time and money goes into their training." In Dr. Culver's area alone, sixty precise measurements were secured in ten different areas of the eye.

The men are given psychiatric and psychological tests. They are tilted and rotated in darkened rooms, and spun in a centrifuge so that the physicians can check the reaction of their hearts. Sketches are made, in another test, of the electrical forces pulsing through their hearts. They are submerged in tanks of water, and the exact amount of water displaced is noted, part of a painstaking effort to determine the precise body density. The X rays, the blood sampling, the needle punctures are beyond counting.

Says Mr. Herron: "It went on for seven days. The end result was a series of reports in each of ten medical areas. Those who survived to final selection are mature men, most of them with 1,800 hours or more of jet-fighter training with the military. Yet as they make the initial move into the program at Houston, they are, in the eyes of the men responsible for molding them, 'a bit like college freshmen, unsure of themselves—but by heavens, they catch on fast!' "

The "Average Astronaut"

IF THERE IS SUCH A THING as an "average astronaut" among the more than seventy trainees selected by NASA, he is thirty-seven years of age, weighs 160 pounds, is about five feet, eleven inches tall. In

Col. John Paul Stapp is strapped into his seat on the rocket sled. Power of nine rockets gave him a speed of 632 mph in 2,800 feet, acceleration of eight g's and deceleration of an astonishing forty g's.

addition to being a test pilot, he holds a Bachelor of Science degree and a Master's degree, and has done some work on his doctorate. He was graduated in the top five of his class from a major university and attended a military test pilot's school. You'll find no women in the American program, although the Russians have already orbited a female. NASA prefers to keep women out—at least for now.

A second, smaller group—more recent to the program—is a different breed. These newcomers are scientists, chosen not for their flying ability but for their experience as physicists, geologists, engineers, medical doctors and astronomers. One of these, a geologist, was earmarked for a moon trip on Apollo 17. Their special skills will be needed for observation

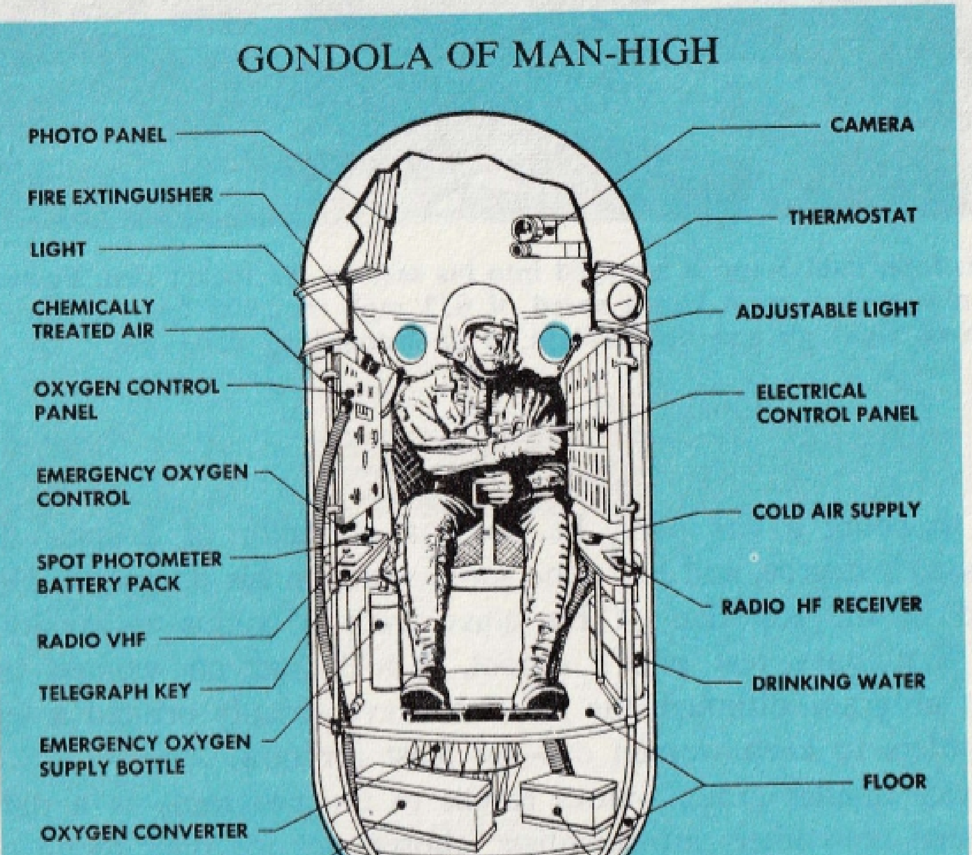
and exploration. Some will carry out scientific investigations closer to earth, in orbiting space stations, or on longer journeys to the planets, when that day eventually comes.

The important thing about all these men is that they are ready volunteers and emotionally well balanced. They are not supermen, but you must admit they are a cut above the average.

Brave Experiments

THE FIRST THING that impresses anyone coming into close contact with the man-in-space program is the massive amount of research that preceded America's first space flight in 1961. Some of these fascinating experiments still are of interest to us all.

Colonel Stapp, one of the "do-it-yourself" physicians, rode rib-shattering rocket sleds in twenty-six tests, once at 632 miles per hour—almost



The huge plastic balloon which carried Lt. Col. David G. Simons to a record altitude of 102,000 feet rises from the open-pit iron mine in northern Minnesota where it was launched.

as fast as a rifle bullet—and came to stops as abrupt as if he were hitting a brick wall. Once at Holloman Field he braked to a dead stop in 1.5 seconds, wound up with a fractured arm, retinal hemorrhage, a pair of black eyes and magnificent proof that man can withstand tremendous jolts for brief intervals, far greater than our astronauts now experience even in the most rugged blast-offs. On one record speed run his body withstood, for a fraction of a second, a force forty times that of gravity.

A moon traveler has to endure only eight to ten "gravities" during the fleeting seconds after he roars off the launching pad from earth. When he starts his return journey from the lunar surface, the pull of gravity is even less, due to the much smaller mass of the moon.

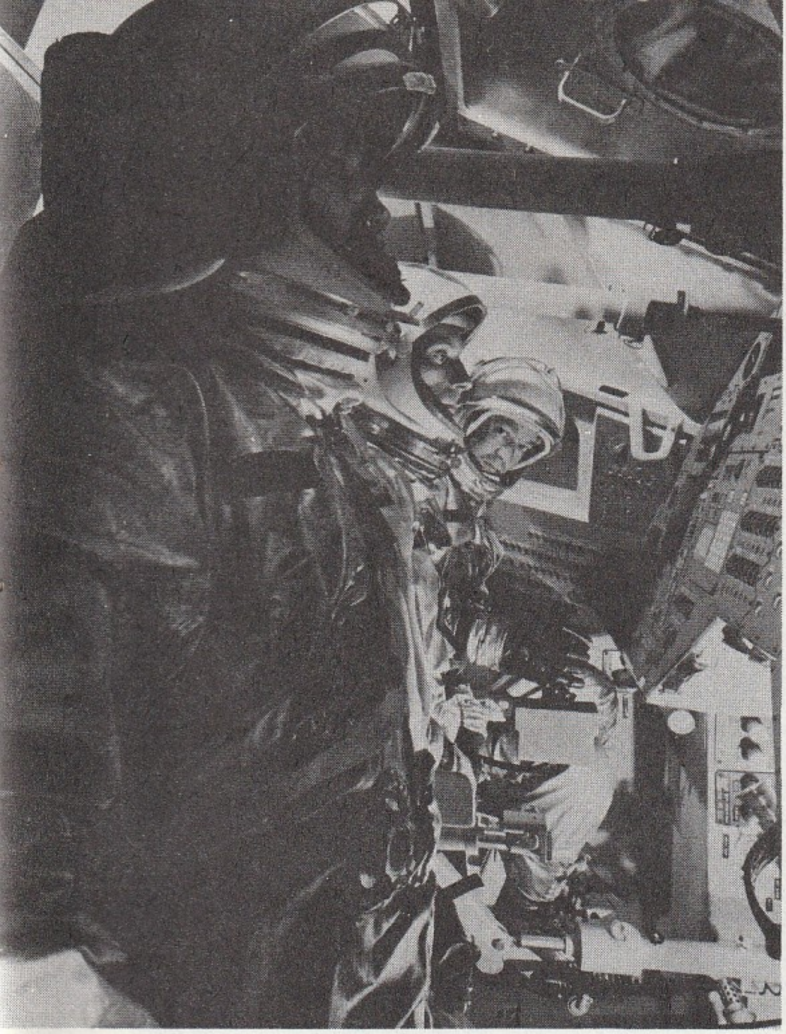
Project Man-High

LT. COL. SIMONS, youngest of the pioneering Strughold-Stapp-Simons trio, was thirty-six when he squeezed into a sealed gondola of a 350-foot-tall balloon and was lifted to a maximum of 102,000 feet—over nineteen miles—into the stratosphere. This was Project Man-High and for thirty-two hours the brave doctor cruised perilously above at least ninety-six per cent of the earth's atmosphere, where air pressure is so low his blood vessels would have burst in seconds if his cabin had been penetrated.

To test further the feared, largely unknown cosmic rays—one of the many projects Doctor Simons carried out in Man-High—experts have even put fungi into balloons. Other early experiments involved dogs, white mice, fruit flies, hamsters and monkeys, all sent skyward in balloons and rockets. The most highly publicized biosatellite (life-carrying capsule), before United States and Russian spacemen made their first manned trips, was Sputnik II and its passenger dog, Laika. Laika assured us that organisms could survive the shock of blast-off. But Laika wasn't the first, either. The fact is that the U. S. Air Force started space-probing tests as far back as 1949, by sending Philippine macaque monkeys up in V-2 and Aerobee rockets. They parachuted to earth and one healthy specimen lived quite comfortably for years at the National Zoological Park in Washington, D.C.

Training . . . Training . . . Training

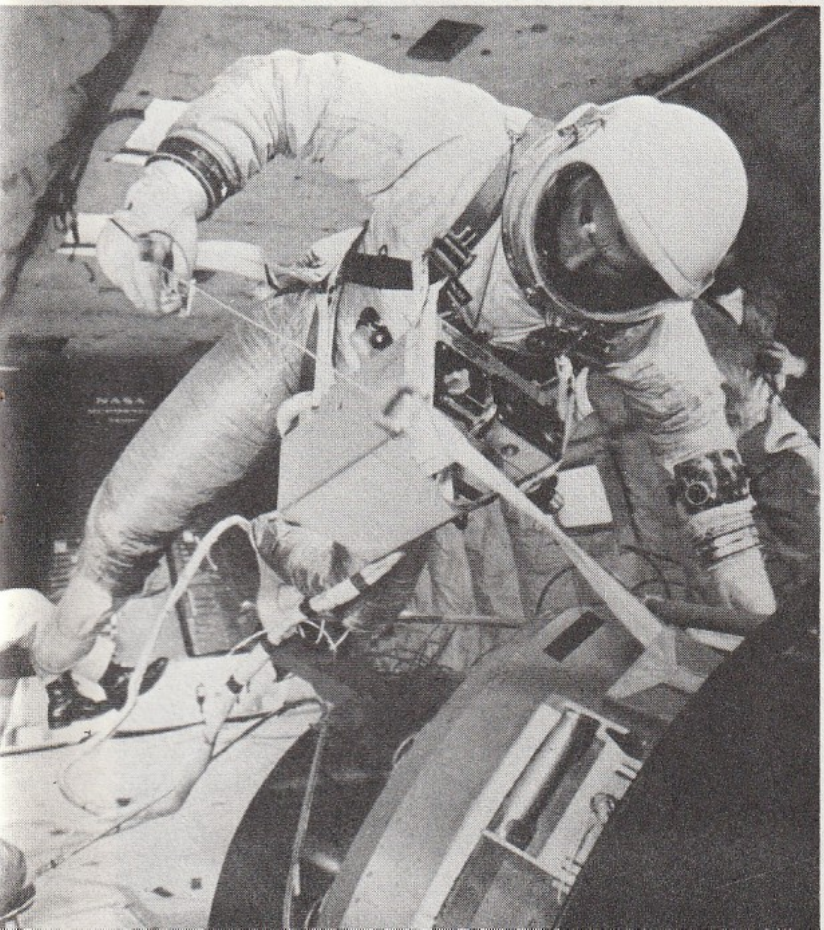
FROM THE EARLY EXPERIMENTS came not only the specifications for building the first space capsules, but important guidelines for today's training programs. Coaches sometimes complain that overtraining hurts an athlete's performance. That is not so with astronauts. Spacemen themselves insist they cannot get enough training for a space flight. Before he straps himself in for his first leap into space, a U.S. astronaut has spent at least two years getting ready. He has gone on whirling rides in the centrifuge, taken jarring jolts in the space cabin

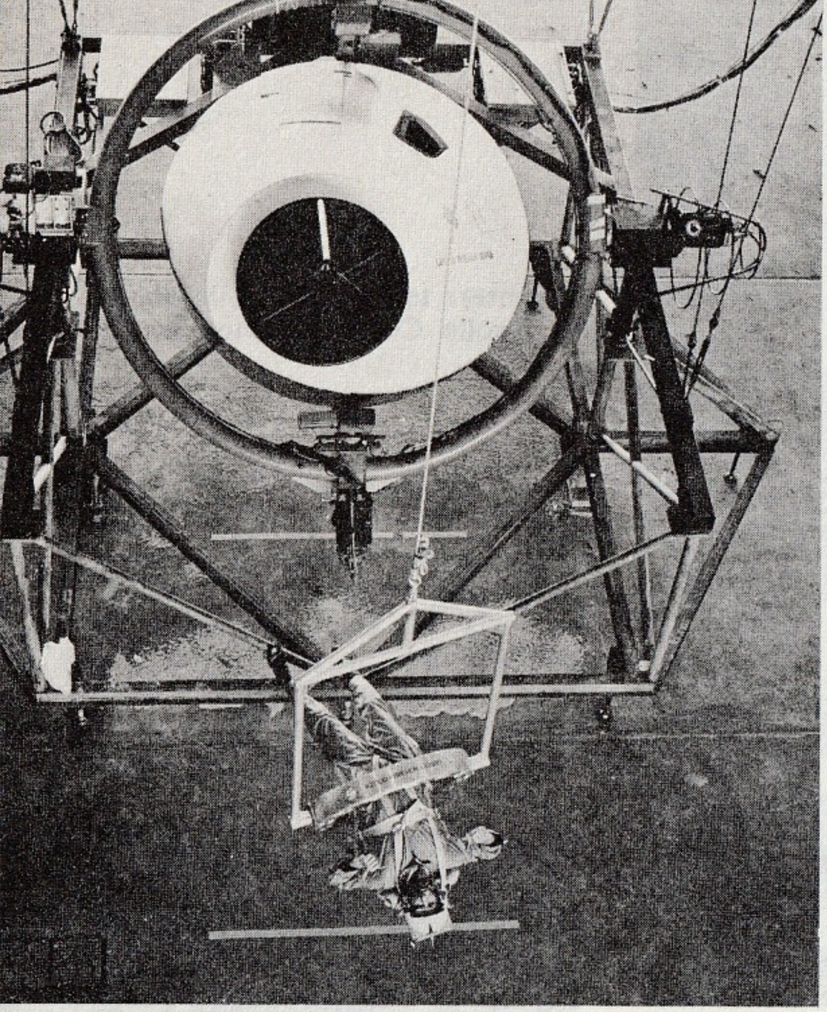


Engineers test space suit flexibility in Apollo Command Module.

A test subject is delicately balanced in every direction in studies of the amounts of energy required to perform tasks in space. The subject's balance on this device is so critical that movement of his finger sends him into sweeping gyrations.

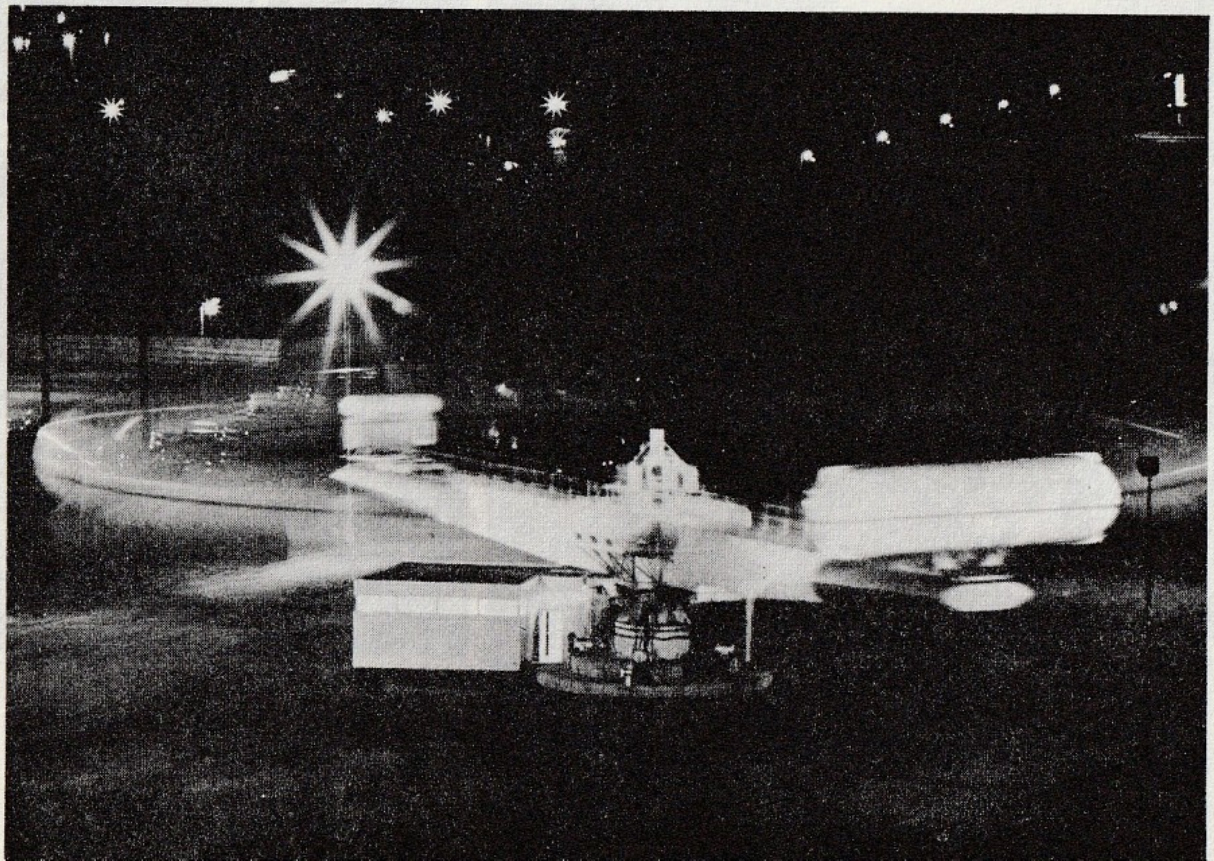
Astronaut Eugene Cernan practises zero "g" flying in preparation for a mission.

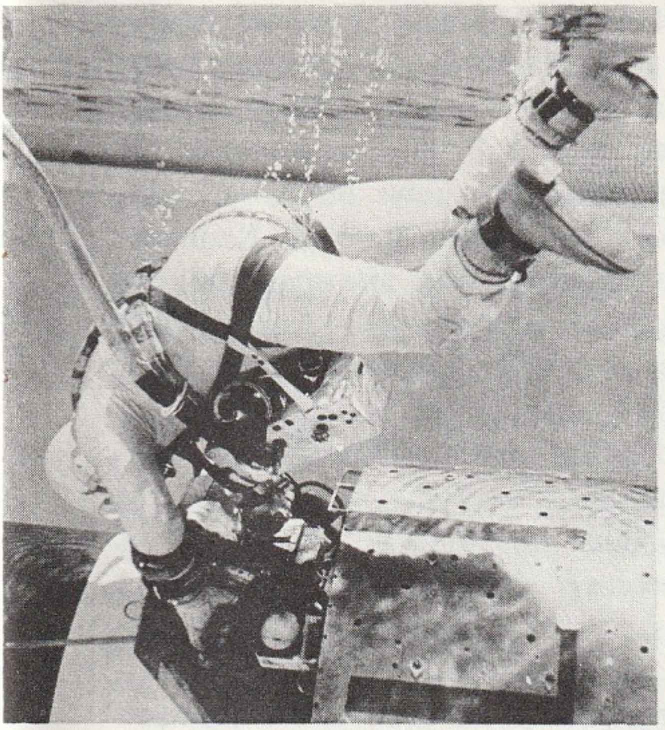




Training with a space-walk simulator, a test subject is suspended within a lightweight gimbal system, an aluminum ring suspended by a cable from an overhead traveling apparatus, which is responsive to servo-mechanism commands. He maneuvers in an area 210 by forty-five by sixteen feet, using a cold gas propulsion system.

Round and round in slow rotation men spin in tests related to long-term space missions. The cabin on the end of the 150-foot beam rotates at about nine rpm. Men spend nearly thirty days in rotational studies.

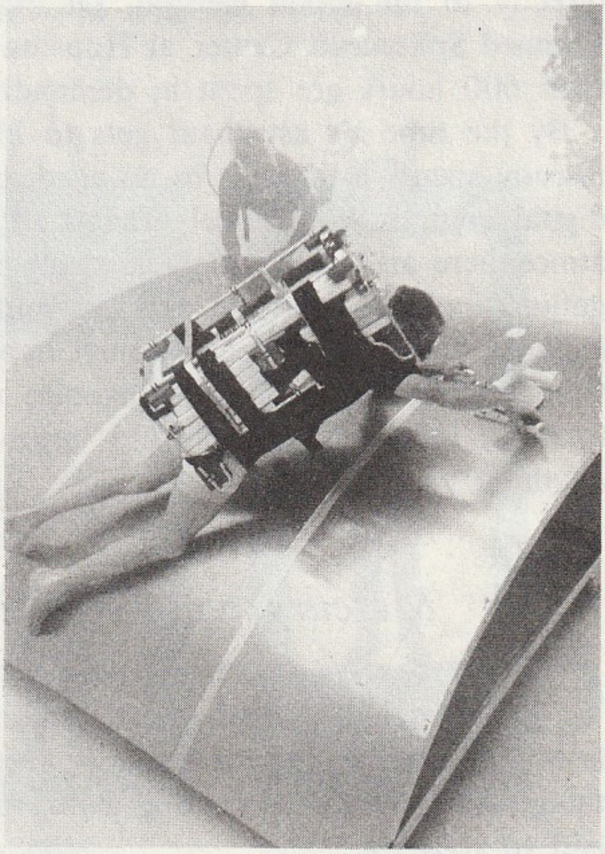




Astronaut Edwin (Buzz) Aldrin practises under water in a swimming pool for his Gemini 12 space-walk. Aldrin is working on the docking collar where the Gemini noses into the Agena target rocket. Aldrin feels water is the best place to simulate on earth the weightlessness of space.

Immersed under water in simulated weightlessness, scientists at NASA's Langley Research Center perform repairs on submerged section of Apollo spacecraft. In other studies, scuba divers, complete with simulated astronaut backpacks, perform such tasks as emerging from and re-entering spacecraft. These studies result in excellent data on the degree of effort required for a wide variety of space activities.

Astronauts practise water-egress training in a swimming pool at Ellington Air Force Base, Houston. A boilerplate model of their spacecraft is at right.



simulator, been dunked in the Gulf of Mexico, practised water escapes in giant tanks, and spent hours in planetariums reviewing celestial navigation. He has studied geological formations over half the world and endured desert-survival techniques in the other half. He has reviewed his flight plans, studied the capsule systems until he knows them by heart, and gone through countless make-believe launchings at Cape Kennedy.

While the training for the Mercury Program was informal and developed largely as the program progressed, Gemini and Apollo were something else. To get an idea of what is involved, consider this: Each two-man crew for Gemini devoted more than 1,300 hours to training for specific flights. They spent 400 hours in spacecraft testing; 300 for travel; 150 in the Gemini mission simulator; 120 flying airplanes; 60 at systems briefings; 45 reviewing flight plans; 40 in task trainers; 25 at planetariums; 20 in capsule escape practice; 20 in the centrifuge and launch-abort exercises; 20 in operations review; 15 in ejection seat tests; 15 in couch and suit fittings, and 90 for overall studies.

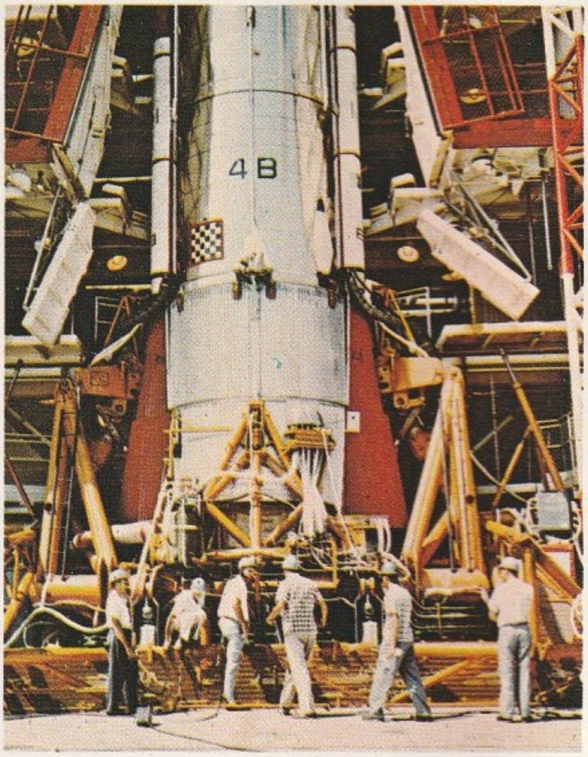
Training for Apollo is even more rigorous than that. After eighteen months of general studies and training, Apollo crews go into a comprehensive forty-week course that places heavy stress on operations related directly to the moon mission. Of that 2,040 hours—about half at the Manned Spacecraft Center at Houston and half at Cape Kennedy—more than 600 hours are spent in demanding spacecraft simulations.

By the time an astronaut gets to his specific mission training, he has already spent six months in an academic program in geology, astronomy, digital computers, medical aspects of space flight, physics of the upper atmosphere and space, flight mechanics, meteorology, guidance and navigation, rocket propulsion and communications. In hundreds of hours of lectures, an astronaut learns about hypergolic fuels and hyperbolic velocities, about everything from cryogenics to comets. The idea is plain enough: to make better astronauts, and improve the chances of survival should anything go wrong.

Mercury and Gemini—Great Successes

GO INTO ANY AMERICAN SPACE LABORATORY and you'll find scientists delighted with the mountains of information already accumulated in just the few years that spacemen have been in action. For one thing, many of the more frightening predictions of pessimists have been laid to rest.

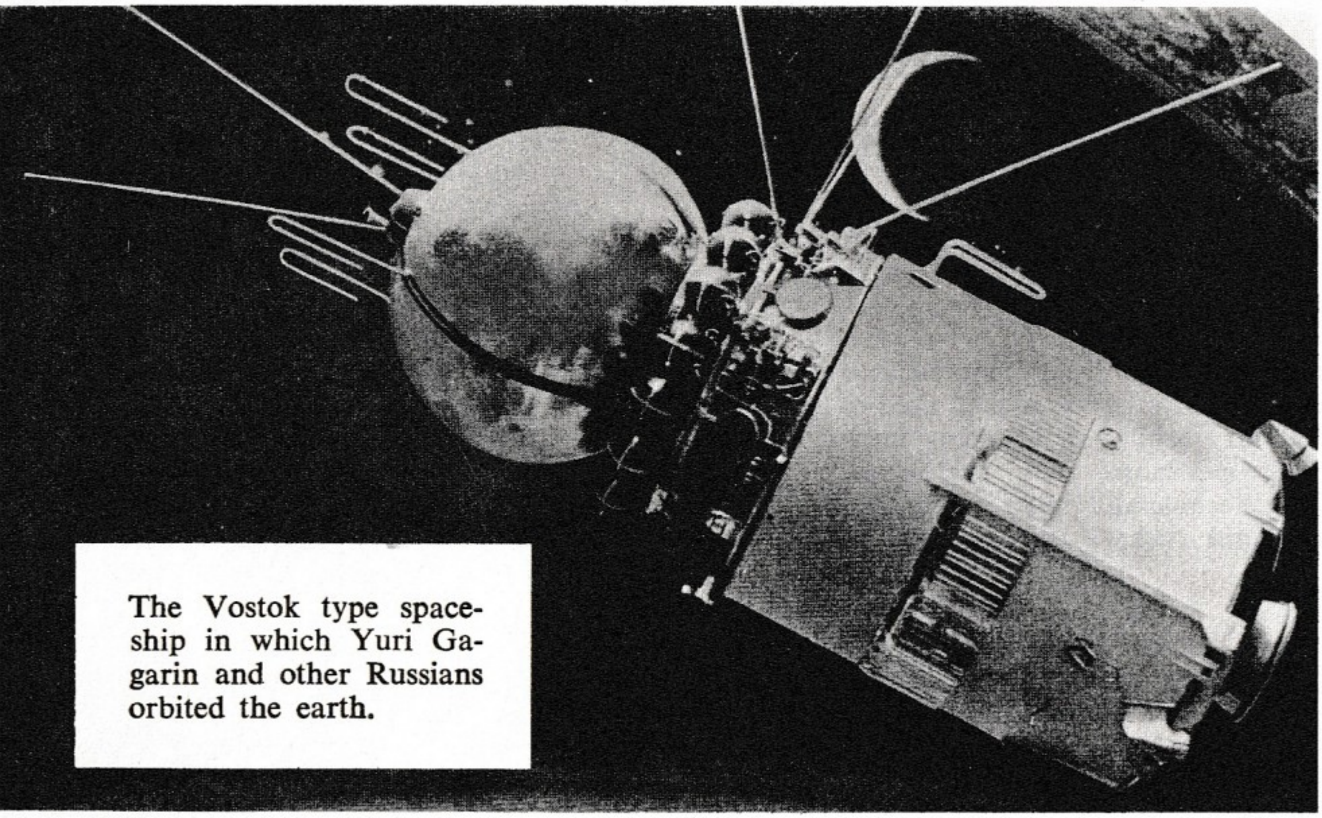
During long and complicated countdown of Atlas rocket, used in Mercury orbital shots, many intricate operations were performed. Here technicians pump liquid oxygen into rocket's tanks.



5. FUELING AN ATLAS

The Mercury program, started in 1961, and the Gemini program, started in 1965, pioneered and then proved out the intricate processes of lift-off, powered flight, ship control, maneuvering and docking in space, tracking procedures, re-entry and recovery at sea. Man's ability to function in space—for two weeks or more—was demonstrated. The result was new confidence, experience and fundamental knowledge. The first orbital flight of John Glenn—just three times around the earth—seems much less daring now in comparison to a flight to the moon, with three days of exploration of the lunar surface thrown in for good measure. But it was flights such as Glenn's that laid the foundation for much that followed.

There were no great surprises in those first flights. Spacemen were grateful for that. The space environment was found to present no natural conditions to interfere with the scheduling of the Apollo missions. Astronauts showed convincingly that not only can they survive, but they can also function as systems operators and as scientific observers and experimenters. Mercury and Gemini also proved that the program for selecting astronauts and training them was basically sound.

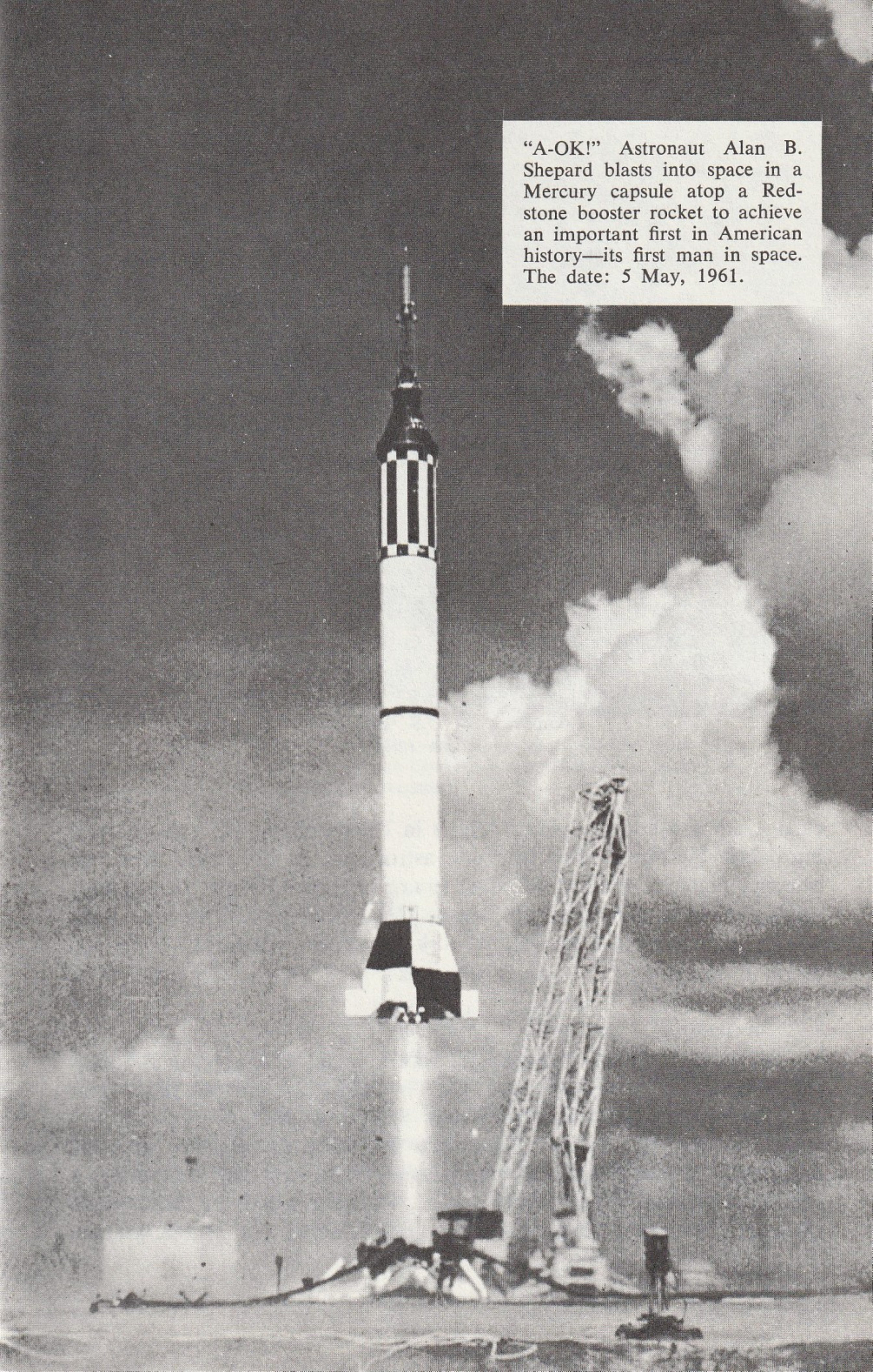


The Vostok type spaceship in which Yuri Gagarin and other Russians orbited the earth.

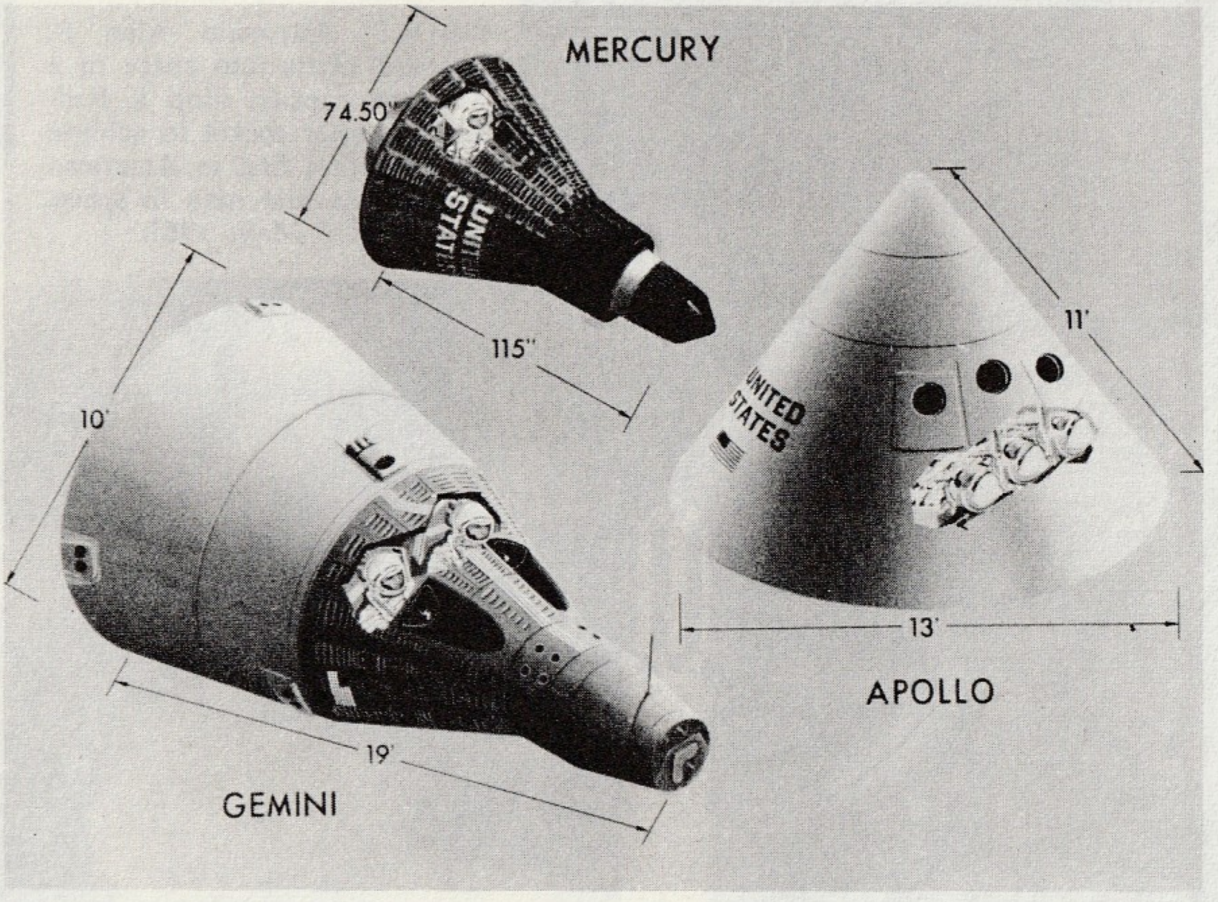
How the U.S. Closed the Gap

AS THE RECORD SHOWS, the United States got off to a slow start in the man-in-space race with Russia. It was left to the Russians, with their more powerful space boosters, to claim most of the important "firsts" of the Space Age. It was the Soviets who orbited the first man—Yuri Gagarin on 12 April, 1961. The Russians followed by orbiting the first two-man "tandem" in 1962, the first woman in space in 1963 and the first three-man crew in 1964. Another dramatic first was Cosmonaut Alexei Leonov's walk through space in 1965.

Once the wheels started turning in the United States program, the gap started to narrow, and eventually disappeared. On 5 May, 1961, less than a month after the first Russian manned flight, an American named Alan Shepard went aloft in a tiny, bell-shaped capsule called Freedom 7. The flight was short—a 15-minute, 22-second ride into space, but not into orbit. The spacecraft was simple—a little one-seater that could not be steered. But the flight of Freedom 7 started America on the way. On 20 February, 1962, John Glenn became the first American to orbit the



"A-OK!" Astronaut Alan B. Shepard blasts into space in a Mercury capsule atop a Redstone booster rocket to achieve an important first in American history—its first man in space. The date: 5 May, 1961.



Comparison of U.S. spacecraft.

earth, with a 4-hour, 55-minute flight in Friendship 7. He was followed into orbit by three other Mercury astronauts. In all, there were six Mercury flights, a total of fifty-four hours in space. Despite that skimpy total, the Mercury program proved to U.S. scientists that manned flight was possible and laid the groundwork for bigger things.

Lessons from Gemini

THE TWO-MAN GEMINI PROGRAM was announced in 1961 as a $500,000,000 series to start in 1964. The first flight did not come until 1965 and its total cost finally reached $1,350,000,000.

By the end of the final flight, late in 1966, the expense and the delay seemed worthwhile. Gemini accomplished virtually everything it set out to do, and actually gave space scientists a bonus by doing some things that were not planned. In one mission alone, the historic Gemini

7/6, it accomplished two major objectives—proving man could withstand the rigors of space for fourteen days and also proving that one vehicle could be brought to a rendezvous with a second vehicle in space. The program proved, with the Gemini 12 space-walk by Edwin Aldrin, that man can overcome space fatigue and do useful work in the weightlessness of space. Gemini's legacy also included the use of fuel cells to provide spacecraft electricity, a compact on-board computer for rendezvous calculations and automatic re-entry, and, more important, the evidence that Gemini could be steered through space by its pilot.

In all, the Gemini astronauts completed ninety of the 111 experiments they carried aloft. The completion of the program gave the United States

Titan II rocket blasts off from Cape Kennedy with James A. McDivitt and Edward H. White II aboard. In addition to White's daring space-walk, the pair orbited earth sixty-six times in their Gemini capsule.

4. GEMINI 4 BLAST-OFF

America's first space-walk, 3 June, 1965. Someday men will move weightless in space and not need the tether that holds Ed White to his Gemini 4 spacecraft. Astronaut White was one of three men who died in Apollo 1 fire at Cape Kennedy in 1967.

a vast edge over Russia in experience. With the Mercury and Gemini totals combined, Americans had logged 1,994 man-hours in space compared with 507 for Russia.

In the Face of Adversity

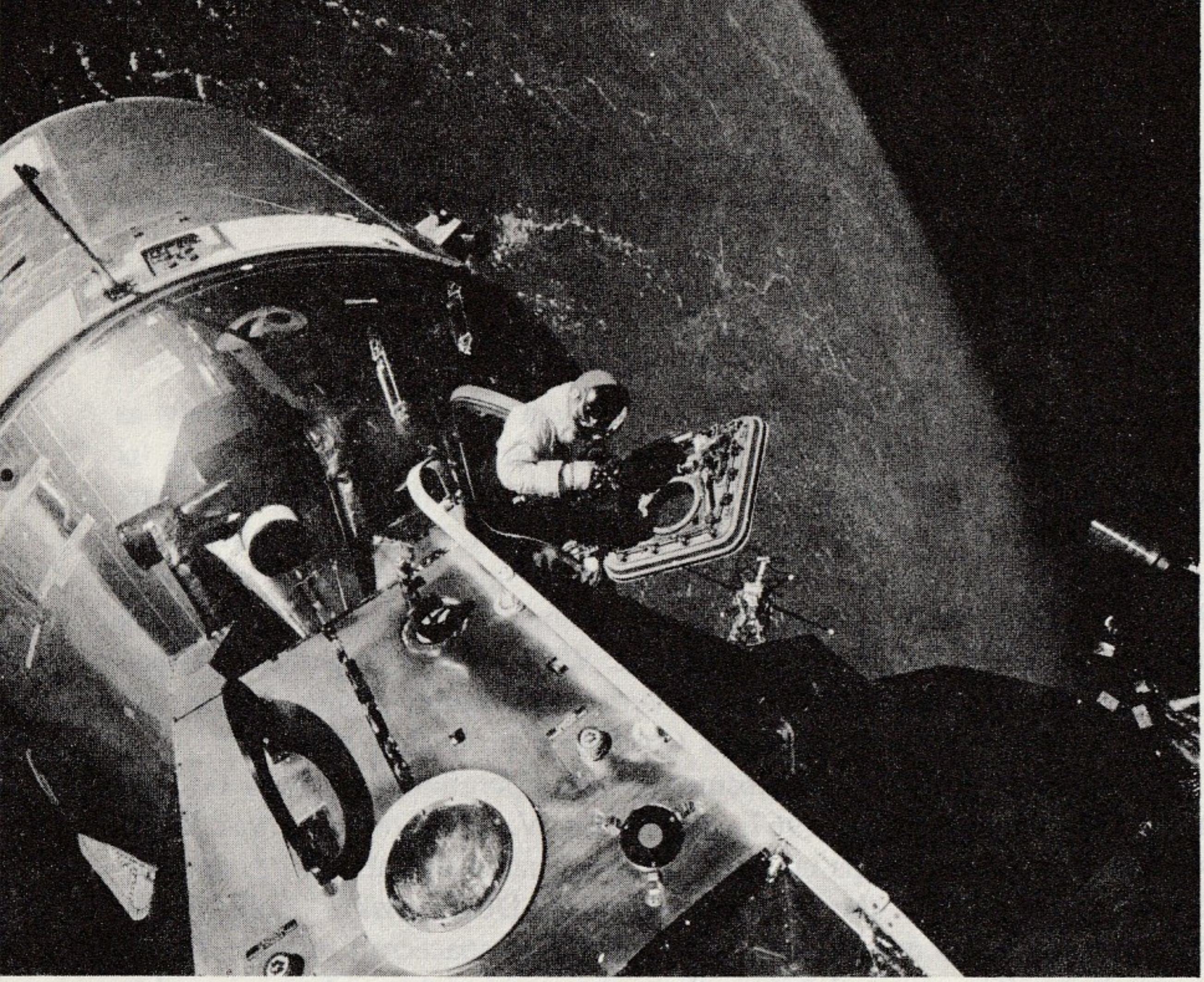
For both the United States and Russia there has been tragedy as well as exhilaration. The first major disaster overtook Apollo 1 on its launch pad on 27 January, 1967. Up to that point three U.S. astronauts had been killed in plane crashes but there had been no fatality in a spaceship. When tragedy did strike, it came in the form of a deadly flash fire that engulfed Apollo 1 during ground tests at the Cape, taking the lives of Virgil I. Grissom, Edward H. White II and Roger B. Chaffee. Grissom was a veteran of both Mercury and Gemini flights, White was America's first space walker and Chaffee a promising rookie.

The Russians had lost four cosmonauts on operational missions through mid-1971. On 24 April, 1967, cosmonaut V. M. Komarov was killed when the parachute straps tangled on his Soyuz spacecraft during descent. On 30 June, 1971, the Russian team of Dobrovolsky, Volkov and Patsayev was killed during reentry of their Soyuz spacecraft into the earth's atmosphere after a record twenty-three days and eighteen hours in orbit. In addition, the first man ever to fly in space, Yuri Gagarin, died on 27 March, 1968, in a plane crash near Moscow.

On to the Moon

These tragedies may have been responsible for the abandonment of the Russian moon-landing program. But the United States pressed ahead. The first moon landing was made by Neil Armstrong and his crew in Apollo 11 on 20 July, 1969. We can get a good idea of what the American missions to the moon are like by following a typical flight plan:

Imagine yourself at Complex 39 at the Kennedy Space Center, on a massive concrete launch pad half the size of a football field. The flight directors are at their consoles. The three astronauts are strapped side by side in contour seats in the Apollo command ship. The Apollo spacecraft consists of three detachable units. On top is the conical Command Module where the three men work and live throughout the flight, except when two of them descend to the moon's surface in the Lunar Module.



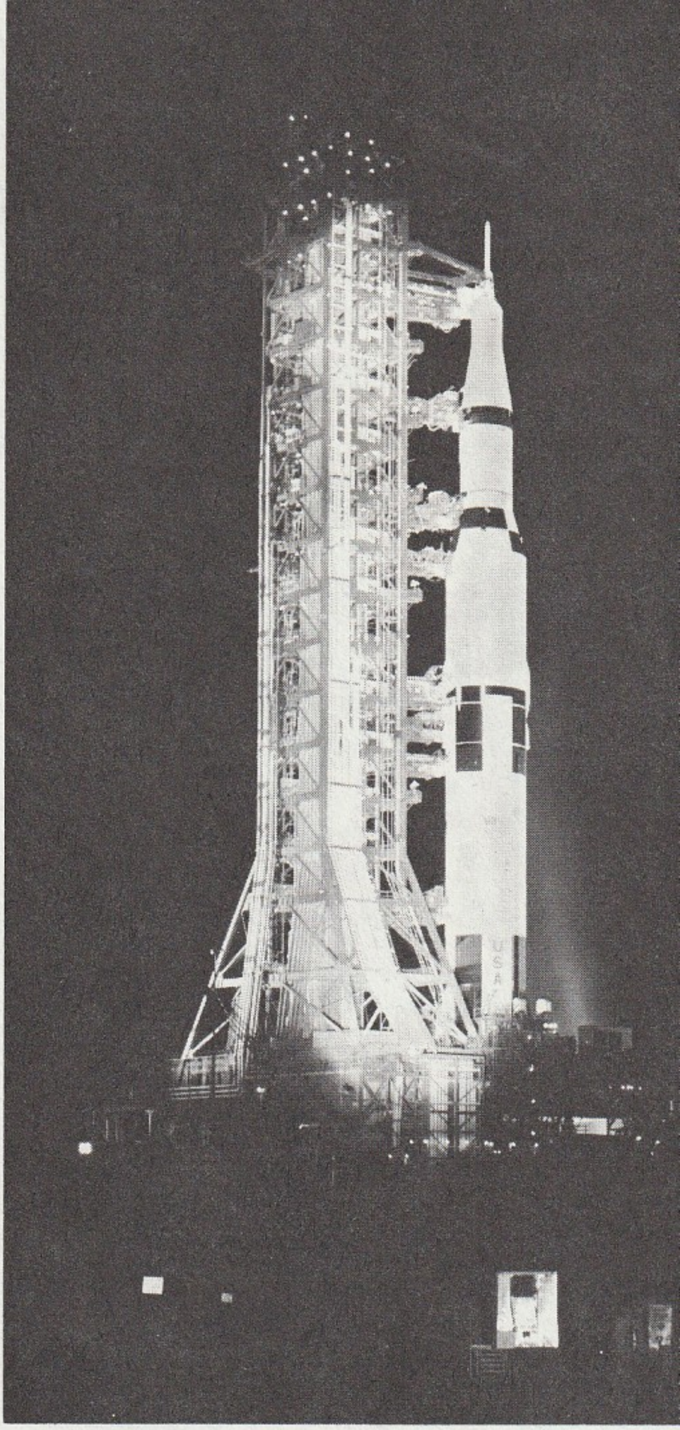
Astronaut David R. Scott stands in the open hatch of the Command Module of Apollo 9 in March, 1969. Command Module is docked with Lunar Module, with earth 100 miles below.

Apollo is luxurious compared to Mercury and Gemini, with hot and cold water and air conditioning set at a comfortable 75°.

Beneath the astronauts is the spherical Service Module, which houses the electrical power system, the environment control system and a 21,500-pound-thrust restartable engine. The Service Module remains attached to the Command Module until just before the astronauts re-enter the earth's atmosphere on the homeward journey.

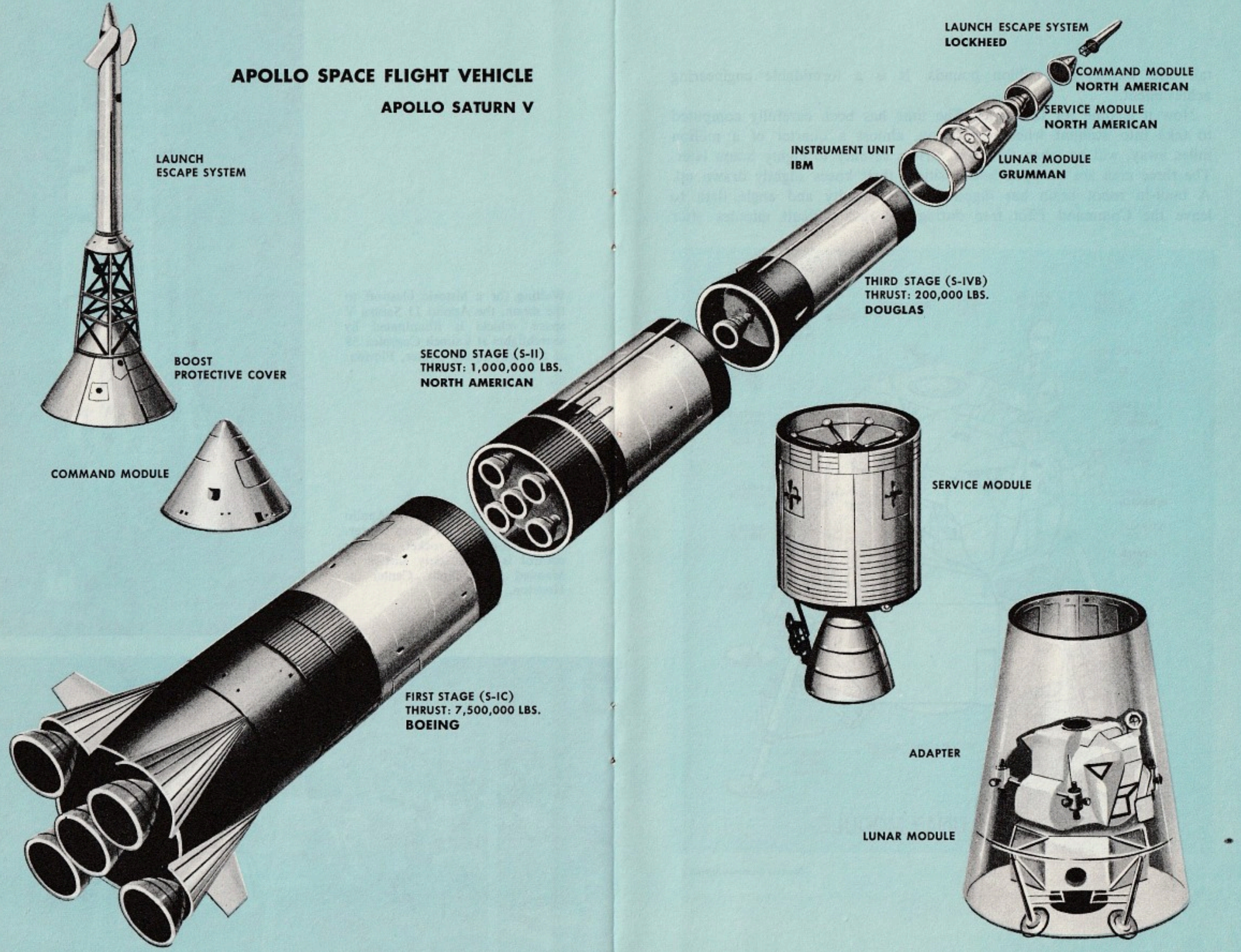
The third unit is the Lunar Module, or LM, which is designed to disengage and carry two of the three astronauts to the lunar surface and later return them to the waiting Command and Service modules in lunar orbit. The LM consists of a buglike cabin set on four spidery cantilevered legs.

From the tip of Apollo's spike-shaped escape rocket to the base of the Saturn V booster, the American moonship stands thirty-six stories



Waiting for a historic blast-off to the moon, the Apollo 11 Saturn V space vehicle is illuminated by searchlights at Launch Complex 39 at Kennedy Space Center, Florida.

Firing control room for Apollo shots at the Kennedy Space Center. After lift-off of rocket, mission control is immediately shifted to Manned Space-flight Center at Houston, Texas.


APOLLO SPACE FLIGHT VEHICLE
APOLLO SATURN V
LAUNCH ESCAPE SYSTEM
BOOST PROTECTIVE COVER
COMMAND MODULE
SECOND STAGE (S-II)
THRUST: 1,000,000 LBS.
NORTH AMERICAN
FIRST STAGE (S-IC)
THRUST: 7,500,000 LBS.
BOEING
LAUNCH ESCAPE SYSTEM
LOCKHEED
COMMAND MODULE
NORTH AMERICAN
SERVICE MODULE
NORTH AMERICAN
INSTRUMENT UNIT
IBM
LUNAR MODULE
GRUMMAN
THIRD STAGE (S-IVB)
THRUST: 200,000 LBS.
DOUGLAS
SERVICE MODULE
ADAPTER
LUNAR MODULE

Science Bulletin

Prepared by SCIENCE SERVICE

". . . ONE GIANT LEAP FOR MANKIND"

On 20 July, 1969, the first men from earth set foot on the moon. It was the culmination of a decade of preparation by American spacemen and signaled victory in what many considered the "moon race" with Russia. The epochal flight of Apollo 11 also signaled the start of further exploration of the moon and, eventually, the near planets of our solar system.

For America, the triumphant flight between 16-24 July marked an amazing comeback from tragedy and despair. On 27 January, 1967, the crew for what was to have been the first manned Apollo flight—Virgil I. Grissom, Edward H. White II and Roger B. Chaffee—were killed in a flash fire that engulfed the interior of their spacecraft during ground tests at the Kennedy Space Center.

More than a year and a half was consumed while the Apollo spacecraft was re-designed for greater safety. Finally, on 11 October, 1968, the way was open for the first of four manned Apollo flights that preceded the Apollo 11 landing.

First came Apollo 7. This initial manned voyage in the Apollo moon program carried three astronauts around the earth for almost eleven full days—actually, 260 hours and 9 minutes. The three were Walter M. Schirra, Jr., R. Walter Cunningham and Donn F. Eisele. The dates were 11-22 October, 1968.

Second came Apollo 8. Between 21–27 December, 1968, a space crew left the gravitational field of earth for the first time, journeyed to the vicinity of the moon, orbited it ten times at an altitude of sixty-nine miles, then breezed home. Crew of that mission: Frank Borman, James A. Lovell, Jr., and William A. Anders. Time in flight: 147 hours, 11 seconds.

Third came Apollo 9. It stayed close to earth to test the lunar module, or LM, for the first time in flight. On this mission between 3–13 March, 1969, astronauts James A. McDivitt, David R. Scott and Russell L. Schweickart were the crew. They orbited earth 151 times. Time elapsed: 241 hours, 1 minute.

Fourth came Apollo 10. This ship went also to the vicinity of the moon, again orbiting it, and sending the LM to within 50,000 feet of the lunar surface. The round trip took 192 hours, 3 minutes, between 18–26 May. The crew: Thomas P. Stafford, John W. Young and Eugene A. Cernan.

Finally came Apollo 11. To Neil A. Armstrong went the honor of becoming the first man to walk on the moon. He was joined by Edwin E. Aldrin, Jr., while the third man of the Apollo 11 crew, Michael Collins, remained at the controls of the orbiting mother ship far above the lunar surface. Elapsed time of the first moon-landing flight was 195 hours and 18 minutes, including two hours that Armstrong and Aldrin spent exploring the moon's surface, taking photos and setting up experiments that they left behind.

Other epochal missions followed Apollo 11's, including one—Apollo 13 in 1970—that was aborted 200,000 miles from earth. In all, seven Apollo moonships were to be launched, with the program ending with Apollo 17 at the end of 1972.

Before taking a closer look at the flight plan followed to the moon, it might be useful to review what preceded Project Apollo. Both the one-man Mercury and the two-man Gemini programs were resounding successes. They are described in detail on the subsequent pages.

MERCURY: SIX PIONEERS IN SPACE

Six American astronauts soared successfully through space in the Mercury Program, two in sub-orbital shots and four in orbital shots.

Alan B. Shepard, Jr. and Virgil I. Grissom first thrilled the country with their sub-orbital flights of 5 May, 1961 and 21 July, 1961, respectively. Their fifteen-minute flights realized a number of major objectives. They pioneered the way for the intricate processes of liftoff, powered flight, weightlessness, re-entry and landing; they evaluated man's ability to function under space-flight conditions.

Shepard flew in a ballistic trajectory 115 miles high and 302 miles downrange of Cape Canaveral, now Cape Kennedy, scene of both sub-orbital flights; Grissom flew 118 miles high and 305 miles downrange; Shepard's missile reached a maximum of 5,280 mph, while Grissom's went a little faster, 5,310 mph; the launch vehicle in both flights was the Redstone III. The capsule containing astronaut Grissom sank in the Atlantic and was lost, but Grissom himself was picked up by helicopter.

Friendship 7, in which astronaut John H. Glenn, Jr. made three orbits on 20 February, 1962, blazed the way for the space-orbital era in the U.S. The three orbits that Glenn made about the earth that day seemed like a lifetime to those who were left earthbound. The capsule, with Lt. Col. Glenn aboard, was recovered in the Atlantic Ocean.

Then M. Scott Carpenter followed with another three-orbit flight on 24 May, 1962. Some anxious moments concerning the astronaut's safety will be remembered, with Carpenter finally recovered, along with his spacecraft, 135 miles east of Puerto Rico.

Walter M. Schirra made six orbits on 3 October, 1962, and traveled 144,602 miles.

The twenty-two-orbit flight of Leroy Gordon Cooper marked the end of Project Mercury. The 1963 flight of

15-16 May broke U.S. time-distance records. Despite re-entry by the manual rather than the automatic control system, the capsule landed within five miles of the prime recovery ship in the Pacific.

There were many similarities in the four flights. The launch vehicle in each case was the Atlas "D" and the liftoff weight was 260,000 pounds. Perigee was 100 miles for all four, with slight variations. Apogee was 163 miles for Glenn, 167 miles for Carpenter, 176 miles for Schirra, and 166 miles for Cooper.

Total flight time was 4 hrs., 56 mins. for Glenn and Carpenter; 9 hrs., 13 mins. for Schirra; 34 hrs., 20½ mins. for Cooper. Distances covered over ground were 83,450 miles for Glenn, 76,025 miles for Carpenter, 144,602 miles for Schirra, and 546,185 miles for Cooper.

GEMINI: TEN SUCCESSFUL FLIGHTS

The Gemini project was particularly important to manned space flight. It was the key to the next step, Apollo.

On 23 March, 1965, twenty-two months after the last Mercury flight, Virgil "Gus" Grissom and John Young flew the first manned Gemini spacecraft three times around the world. The flight marked the first time that a spacecraft had been "steered" from orbit to orbit.

On 3 June of the same year, Edward White became the first man to take a controlled walk through space. Together with pilot James McDivitt, White spent four days in orbit around the earth, twenty minutes of which were outside the spacecraft, as part of the second manned Gemini flight, GT-4 (the first two Gemini flights were unmanned). Using a hand-held "space gun", White was able to maneuver quite comfortably and was enjoying himself so much that it was only after considerable persuasion on the part of both McDivitt

and controllers on the ground that he returned to the capsule.

On 21 August, 1965, GT-5 was launched, with astronauts Gordon Cooper and Charles Conrad, Jr. aboard. They set all kinds of records, not the least of which was eight days in orbit. Since they encountered a malfunction in the fuel cells, which threatened to use up their fuel too quickly, they spent two days tumbling in space without corrective measures. It later became apparent that the fuel would have been adequate.

GT-7, launched 4 December, 1965, set new records for time in space with astronauts James A. Lovell, Jr. and Frank Borman, then came within six feet of GT-6, sent up to meet it on 15 December, carrying Walter Schirra and Tom Stafford.

The flight of Gemini 8 was cut short abruptly in what was fortunately prevented from becoming America's first space fatality. Astronauts Neil Armstrong and David Scott were forced to terminate the first unsuccessful space docking maneuver when their spacecraft began to tumble uncontrollably. Among the experiments that never got carried out was Scott's one-and-a-half-orbit space walk. The docking, however, was a milestone of the Space Age.

GT-9 was to have been crewed by Elliott See and Charles Bassett, but their tragic death in a plane crash forced a shuffling of the roster for future missions. In their place were named one-time veteran Tom Stafford and rookie Eugene A. Cernan. The trip included a little of everything: a space walk, several docking attempts, and "inside" experiments.

Gemini 10, with John Young and Michael Collins aboard, rendezvoused with an Agena target vehicle and shot out to a record altitude of 476 miles. Collins poked half his body out an open hatch in a fifty-five-minute "space stand." Collins also took a half-hour space walk. Flight lasted forty-four orbits.

Gemini 11 took Charles Conrad, Jr. and Richard F. Gordon, Jr. to a rendezvous and docking with an Agena in a record time of 90 minutes, then the pair fired the

Agena for a new altitude mark of 850 miles. The space walk by Gordon was cut short by exhaustion after 44 minutes. Trip lasted forty-three orbits.

Gemini 12, the final shot in the series, took place between 11-15 November, 1966. James A. Lovell, Jr. and Edwin E. Aldrin, Jr. caught an Agena during the third orbit. Aldrin became champion space walker with two space stands of 3 hours 29 minutes and a space walk of 2 hours 9 minutes. Flight ended after fifty-nine orbits. All the Gemini shots were boosted into orbit by a Titan II.

APOLLO: THE FIRST "TOUCHDOWN"

The goal of Project Apollo, from its inception in 1961, was to put men on the moon and return them safely to earth before the end of 1969. Apollo 11 made it with months to spare.

The Apollo spacecraft is eighty-four feet tall and weighs about forty-five tons. It is divided into three modules, an adapter and a launch escape system. First is the Command Module, the only section that returns to earth. It contains the crew's living compartment, plus all controls for the various in-flight maneuvers. Shaped like a shallow cone, this module has a bottom width of 13 feet and stands about 11 feet high. Take-off weight is about 11,000 pounds. The double-walled pressurized chamber has three windows in front of the astronauts' couches, and two side windows.

More elaborately equipped for human comfort than either the Mercury or Gemini spacecraft, the Apollo Command Module enables its crew to keep in touch with earth by television as well as by radio.

Perched on top of the Command Module is the Launch Escape System tower with rocket motors, much like that of Mercury. It stands 34 feet tall and weighs 6,600 pounds, giving the Apollo spacecraft, without its booster, but including all three modules, a total

height of some 84 feet, almost as tall as the combined Mercury-Atlas vehicle that orbited John Glenn.

The tower and motors are jettisoned after the booster's second stage ignites. The system would be used only in a launch emergency situation.

Beneath the crew's command section is the Service Module, a cylindrical unit 12.8 feet in diameter and 14 feet tall, weighing 50,000 pounds. Besides housing the electrical power supply equipment, it also contains the primary propulsion system which produces 22,000 pounds of thrust. Its stop-and-restart engine is used for several important maneuvers, such as mid-course correction during moon approach, slowing down to go into lunar orbit, takeoff from lunar orbit to earth and mid-course corrections while earthbound.

Having fulfilled these tasks, the Service Module is finally jettisoned just before the Command Module re-enters earth's atmosphere.

Under the Service Module, at launch, is the section that acts both as the adapter joining the spacecraft to its launch rocket, and as housing for the LM (Lunar Module),the lunar landing vehicle. The adapter section is a truncated conical shell 29 feet tall and 13 feet wide at the top. At the bottom it flares out to a diameter of 21.6 feet, in order to match the width of the Saturn V booster's IV-B top stage. Weight of the adapter housing is 4,000 pounds.

The LM, weighing approximately 30,000 pounds, is the flight unit that detaches from the orbiting Command and Service modules and descends to the moon's surface with two of the three astronauts aboard. The final descent can be slowed to a feather-like drift, but if the LM should drop like a stone, its jointed steel-truss legs can take up the landing shock without harm.

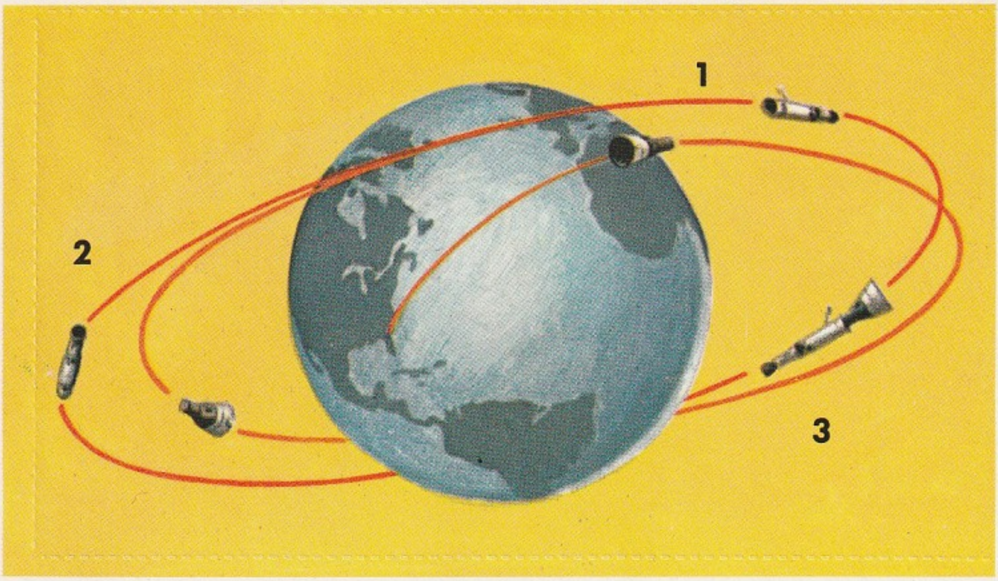
The LM is a two-stage vehicle. The bottom stage contains the rocket engine and legs for lunar landing. This is detachable and forms the launch platform for the upper stage, which is a cabin for the astronauts. Attached to the upper stage is the rocket engine to

propel the stage from the lunar surface back to the awaiting Command and Service modules.

The average exploration on the moon has varied, from two hours in the case of Apollo 11, to nearly eighteen in Apollo 15. After their exploration is completed, the two moon explorers return to the upper section of the LM. The lower section of the LM remains on the moon while the two astronauts blast upwards to meet the third astronaut, remaining in the CSM, from sixty to eighty miles high, for rendezvous and docking. Then the LM is jettisoned and left in moon orbit.

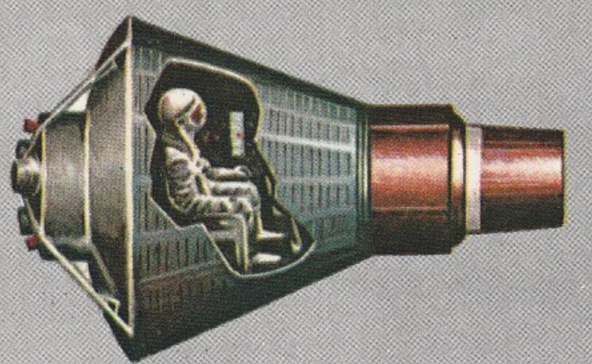
With a re-entry speed of 24,600 miles per hour, the return to earth's atmosphere is trickier than for Gemini and Mercury, which re-entered at about 17,000 miles per hour. Apollo must enter the top of the earth's atmosphere to switch into the proper ballistic path. Friction with the atmosphere produces temperatures of 5,000° F., and the safe re-entry corridor is only forty miles wide. The angle of approach must be kept between 5½° to 7½°. As on Mercury and Gemini, the bottom heat shield protects the crew as air resistance rapidly cuts velocity to a safe point for parachute deployment and landing.

Just as Columbus' voyages to the New World did not end the exploration, but rather brought the start of an entirely new era, so the moon landing mission is regarded as a beginning, rather than the end, of the man-in-space program. The moon, in time, may become the gateway to the solar system.



MAN IN SPACE

A

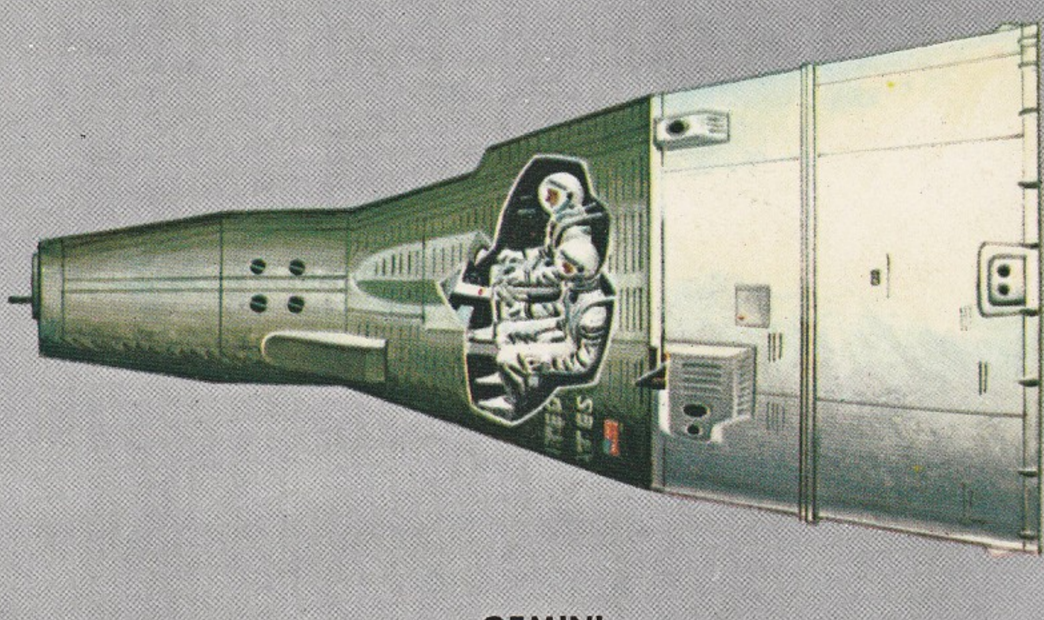


MERCURY

2

6' MAN

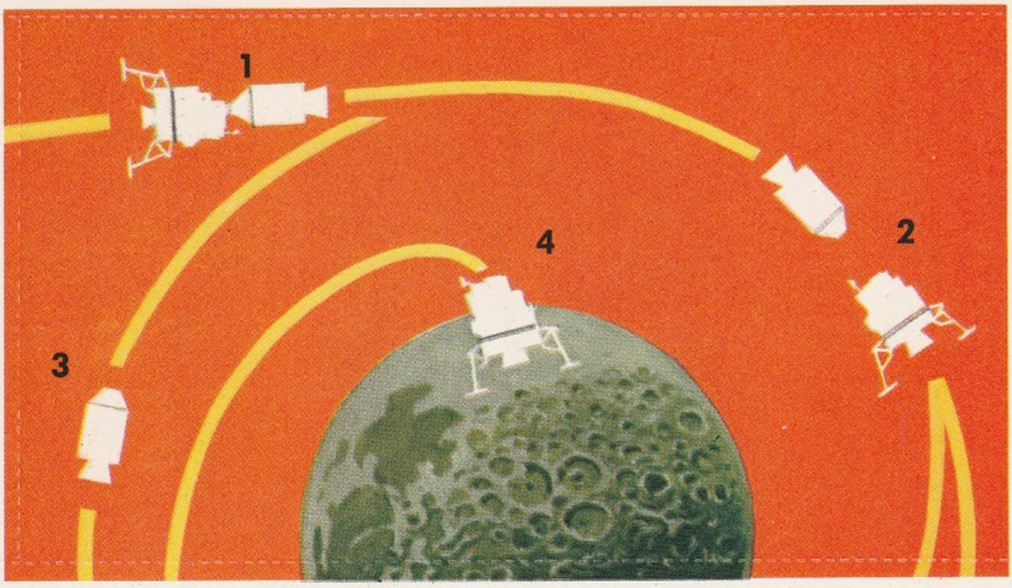
1



GEMINI

3

Punch out and stick on space chart



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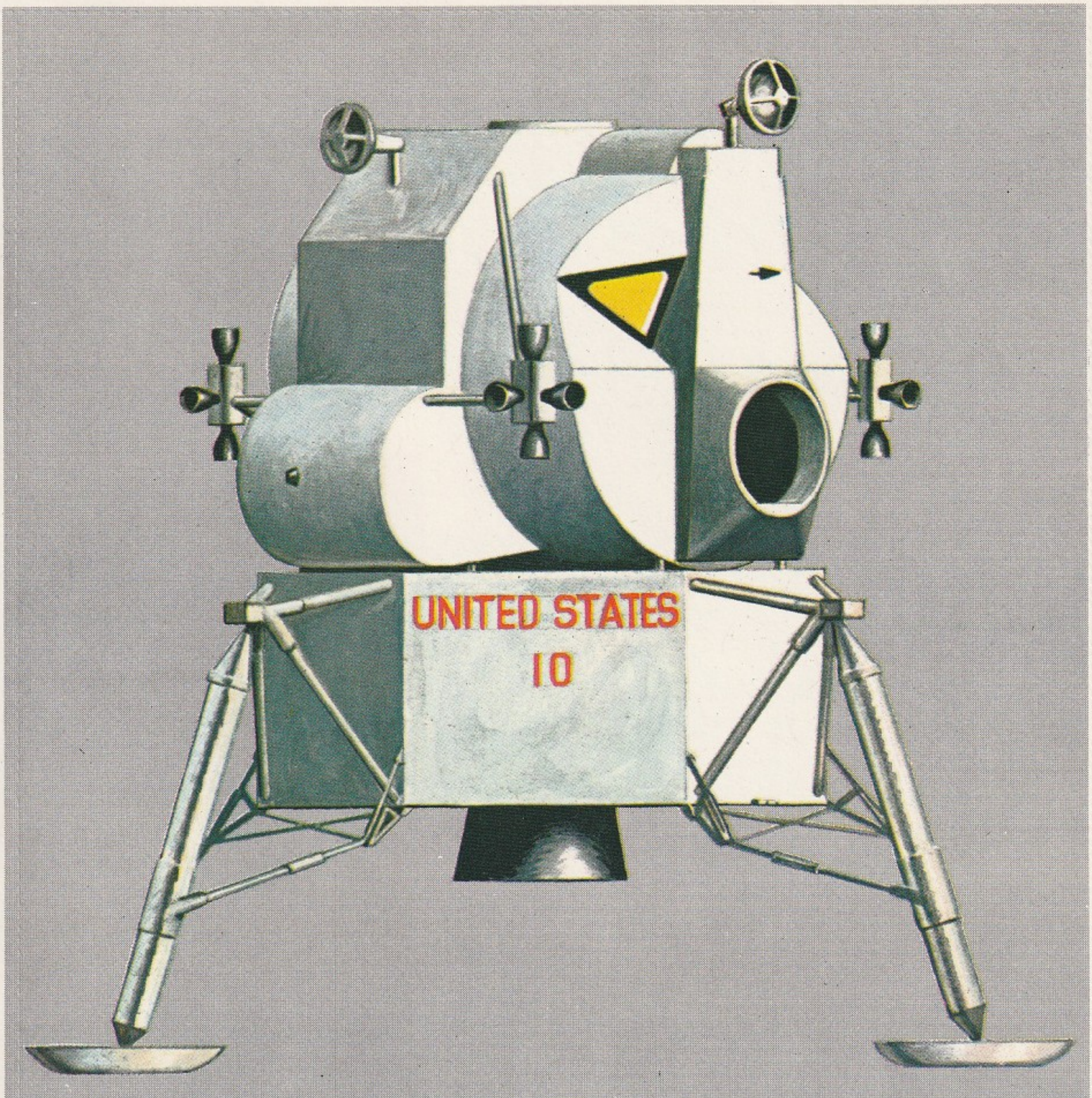
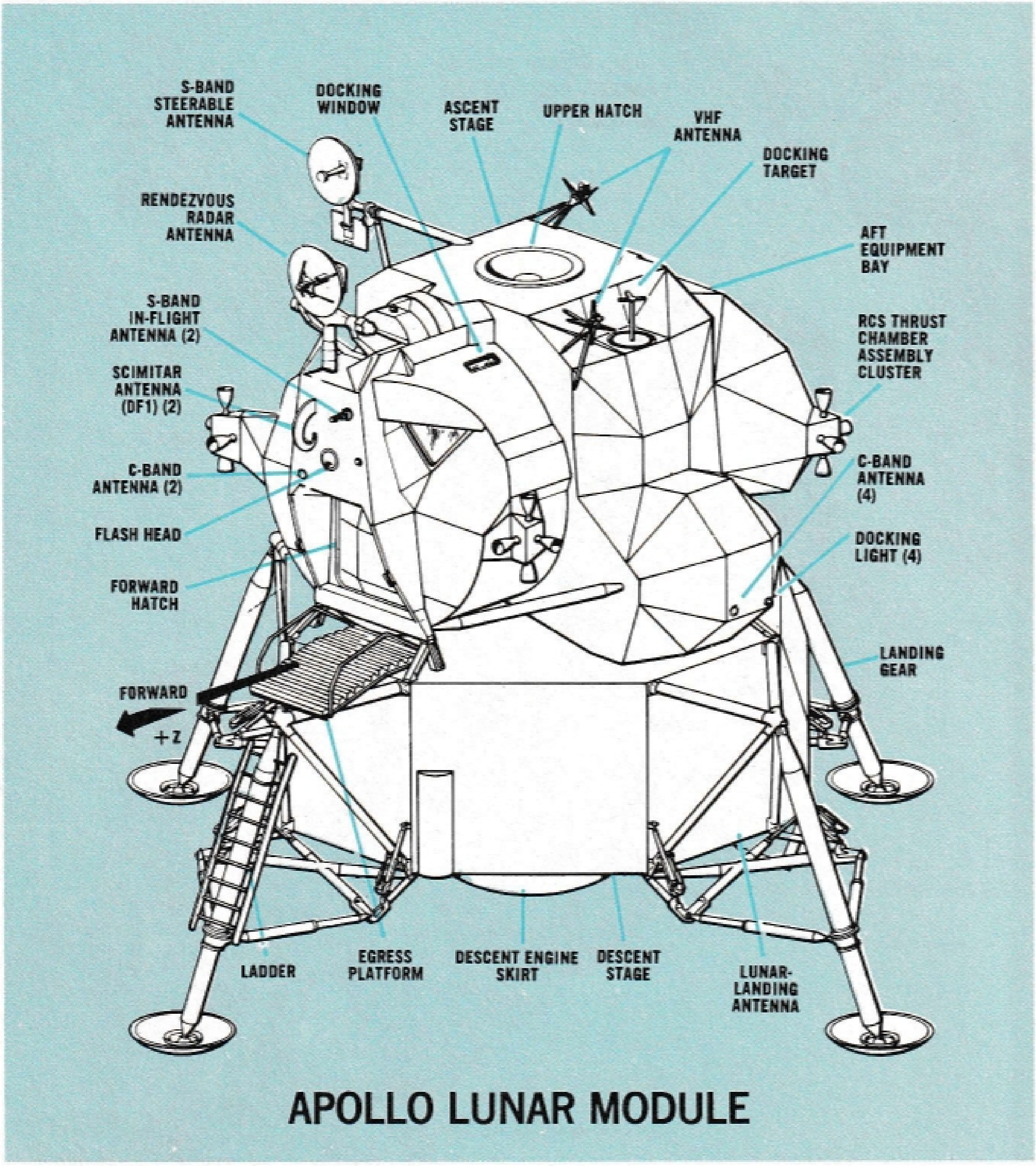


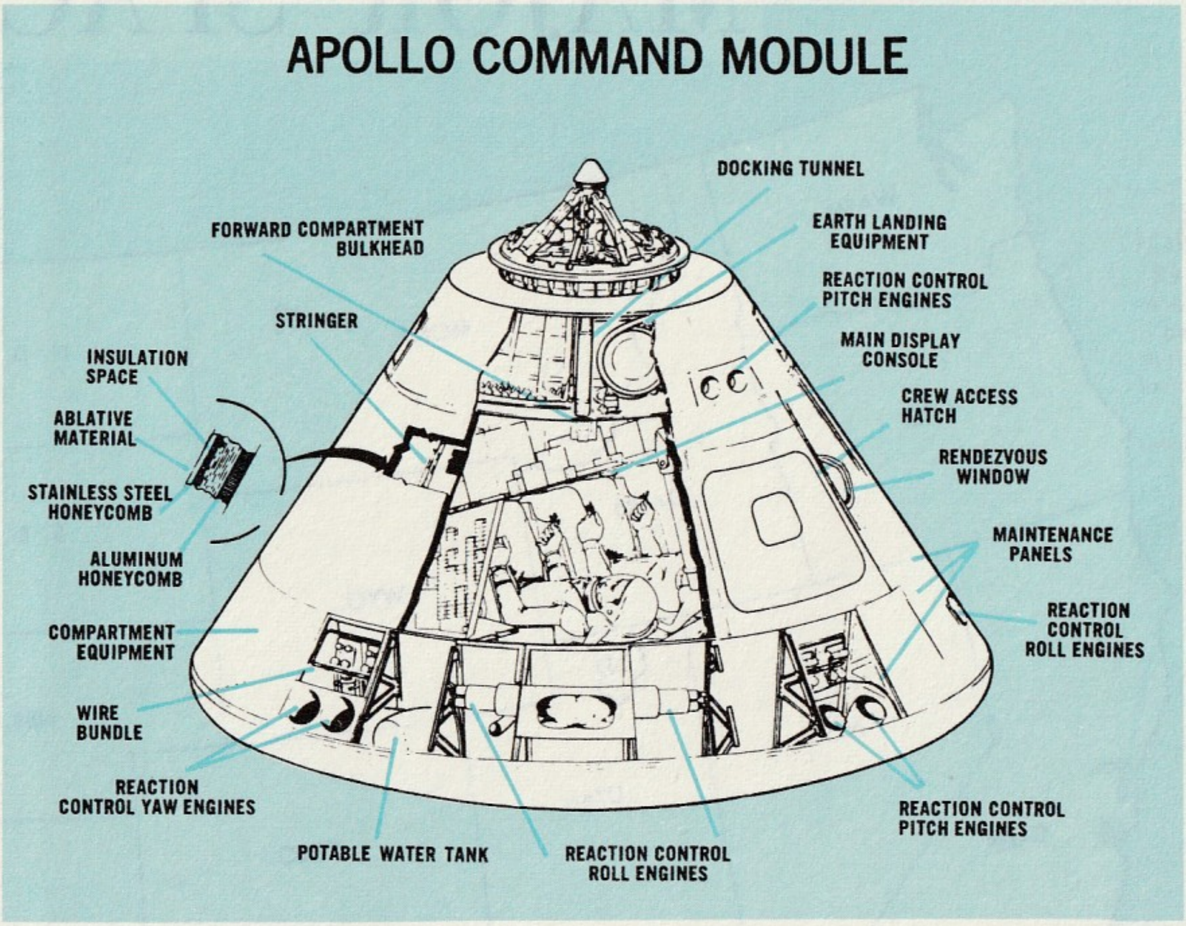
LUNAR MODULE (LM)

tall and weighs 6.1 million pounds. It is a formidable engineering achievement.

Now it is time for launching. The time has been carefully computed to take into account where the moon, almost a quarter of a million miles away, will be when the crew arrives seventy to eighty hours later. The three men are strapped into position, their knees slightly drawn up. A built-in robot brain has digested early velocity and angle data to leave the Command Pilot free during the first difficult minutes after



—Courtesy Grumman Aircraft



—Courtesy North American Rockwell

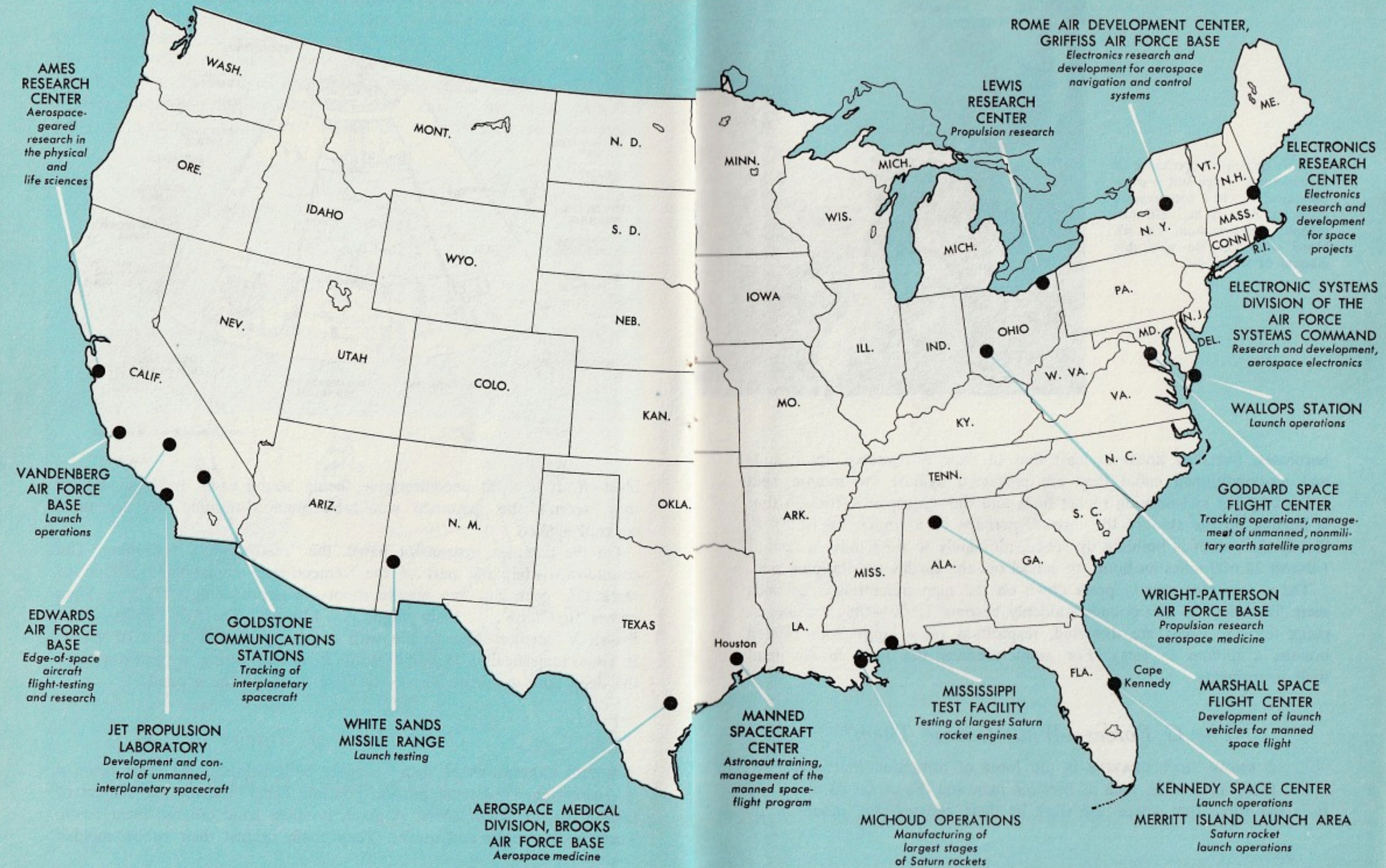
blast-off. It is a bit uncomfortable, being bound arms and legs. But if they weren't, the spacemen would be bounced around like ice in a cocktail shaker.

On the complex instrument panel, the "ready light" is flashing. The countdown—the final part of the tremendously complicated mound of work that goes into any missile shoot—is approaching "T" . . . Then comes "Ignition! . . . Main stage! . . . Lift-off!" The five engines of the Saturn V booster come to life with a great gush and a hiss of vapor. It rises majestically. But not until it starts cutting a pathway into the deep blue dome of the sky is there relief on the ground.

Giant Hand of Gravity

IN THE EARPHONES of their specially built helmets, the crew hears a reassuring word from mission control. Then suddenly the impact of take-off engulfs their senses. A giant, invisible hand crushes them down. Their bodies shake and quiver. They chafe against their rubber-molded

MAJOR SPACE INSTALLATIONS



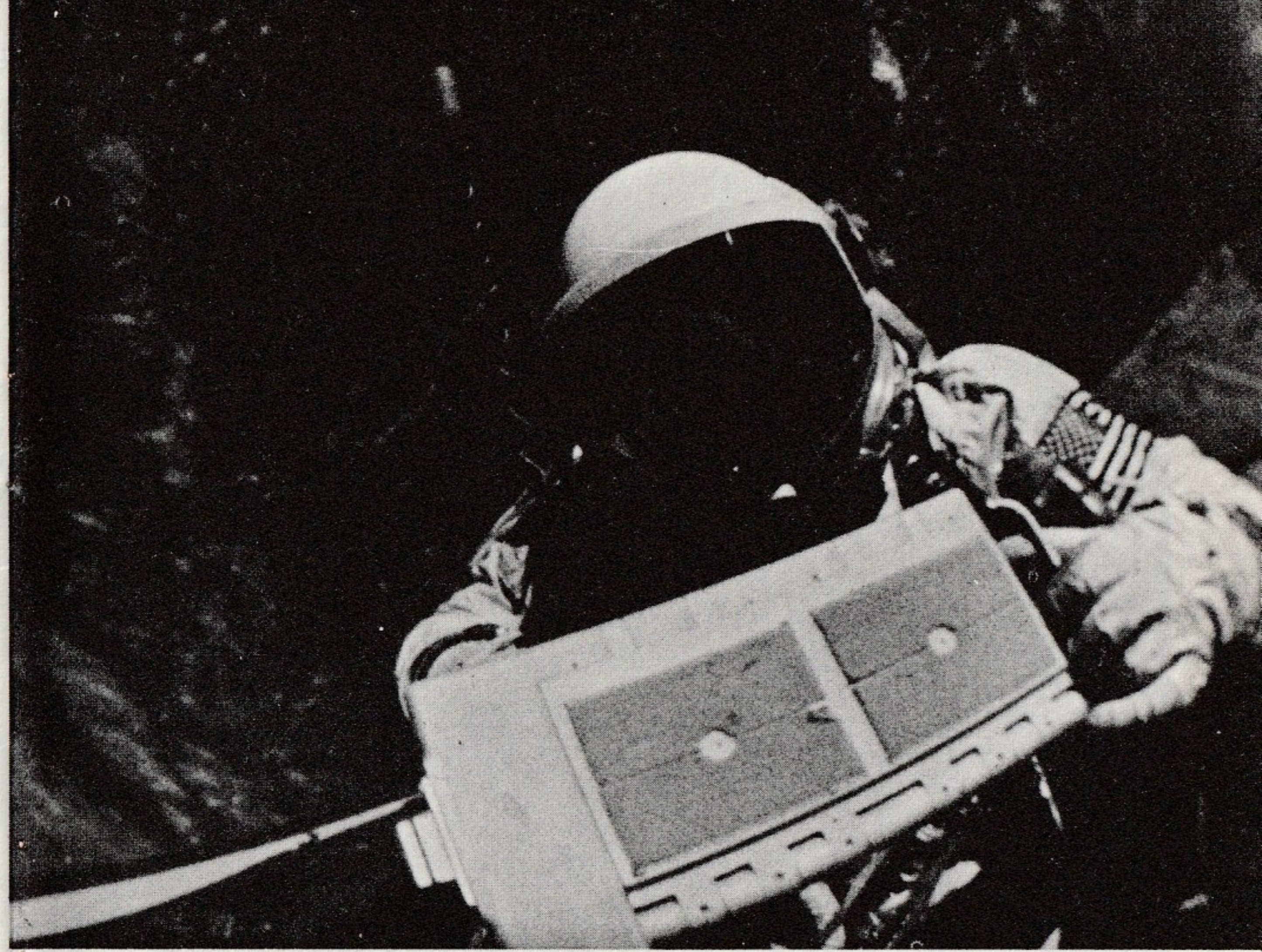
The life or death importance of a pressurized space suit is demonstrated here in a compression chamber. At very high altitude, without pressurization, a man's blood will boil the way this glassful of water did.

harnesses, but they know at least that in their refrigerated space suits and air-conditioned cabin they are protected against the intense heat created by the fast-burning rocket fuels and the atmospheric friction that is heating up the skin of the missile, perhaps to as much as 1,500° F. Slowly the rocket is building up speed, ultimately to 6.83 miles a second (almost 24,600 miles an hour) to cancel out the earth's gravitational pull.

The *g forces* of gravity press down on the men, relentlessly. Seconds seem like hours as 150 pounds suddenly become 1,500—they are undergoing ten g's. Faces are distorted, respiration rates jump from sixteen breaths a minute to forty. For many seconds the men cannot read their instruments.

The G Forces—What Causes Them?

WE KNOW THAT GRAVITY is the force of attraction that exists between all bodies, such as between man and the center of the earth. It is the force that keeps the stars in their courses, the moon in its

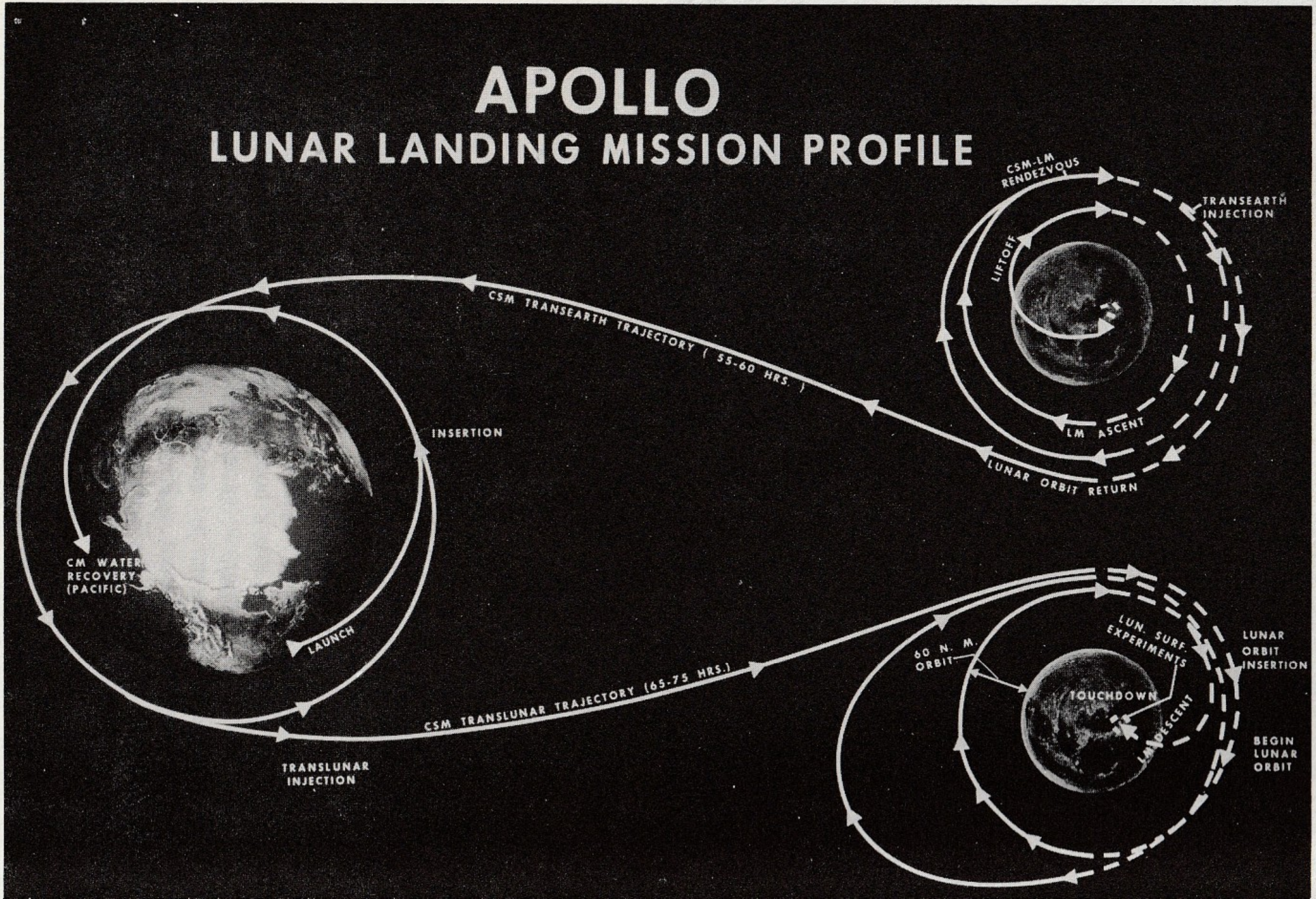


Despite weightless condition, astronauts can perform work in space. This is Edwin Aldrin carrying a micrometeoroid package outside his Gemini 12 spacecraft.

orbit around the earth and sun. Sir Isaac Newton defined the magnitude of this force as being proportional to the product of the masses of the bodies, and inversely proportional to the square of the distance between them.

At sea level, the force of gravitational attraction between a man and the earth is equal to the man's weight. One g is a unit of acceleration exerted on man's body by the earth's pull at sea level. One g is a constant (though it varies minutely from place to place) at thirty-two feet per second per second.

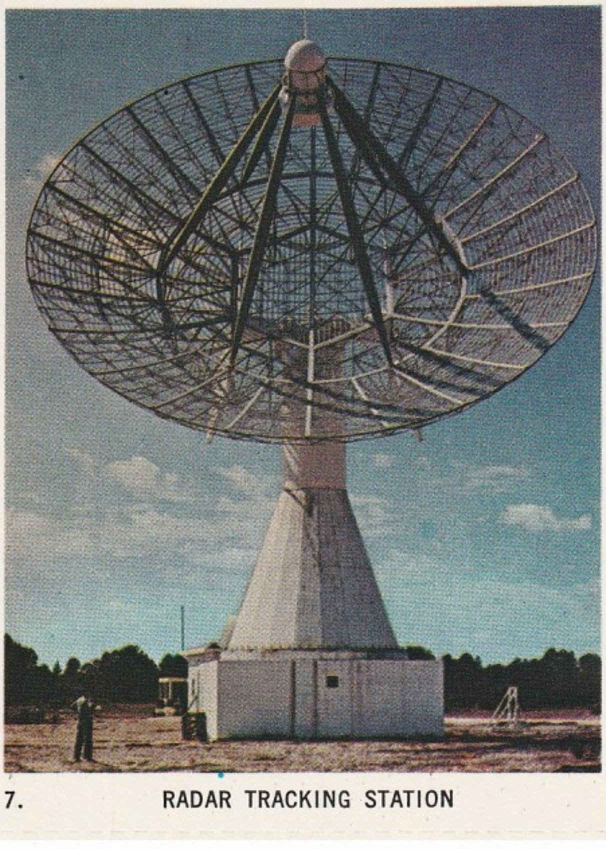
An astronaut's apparent weight increases when the great speed of the escaping rocket pulls against the inertia of the astronaut's body, which is acting like an inert sack of cement that resists being pulled.


APOLLO
LUNAR LANDING MISSION PROFILE
CSM-LM RENDEZVOUS
TRANSEARTH INJECTION
LIFTOFF
LM ASCENT
LUNAR ORBIT RETURN
CSM TRANSEARTH TRAJECTORY (55-60 HRS.)
INSERTION
CM WATER RECOVERY (PACIFIC)
LAUNCH
TRANSLUNAR INJECTION
CSM TRANSLUNAR TRAJECTORY (65-75 HRS.)
60 N. M. ORBIT
LUN. SURF. EXPERIMENTS
TOUCHDOWN
LM DESCENT
LUNAR ORBIT INSERTION
BEGIN LUNAR ORBIT

(*Left*) Diagram of a Saturn V lift-off from Cape Kennedy, Florida, through a lunar landing and return to earth in the Pacific Ocean.

Inertia is a property of all matter by virtue of which any body resists a change of position. The higher the speed, the greater the pull, and the greater the body's reaction to being pulled. This has the same effect as increasing the force of gravity on the astronaut until, in a ten g blast-off, he presses as hard against the surface accelerating him ahead as if his weight had increased ten times.

A man in an auto experiences a slight increase in g force when the car starts with a jerk, throwing him to the back of the seat. But this is very minor. At ten g's the astronaut's arms are too heavy to lift. His eyes wander out of focus. This all adds up to a serious medical situation but one that fortunately doesn't last long—say two minutes, sometimes a few seconds longer. Fortunately, there are no aftereffects. Once he has gone through the acceleration phase, the astronaut returns quickly to normal. That is known from the accounts of all the Mercury, Gemini and Apollo pilots.



7. RADAR TRACKING STATION

Powerful radar tracking stations, such as shown here, keep careful track of the astronauts.

Setting the Course

THE FLIGHT CONTINUES. After two and a half minutes, the 138-foot first-stage Saturn booster, generating 7.5 million pounds of thrust, burns out about thirty miles up and is automatically separated from the rest of the rocket. Then the eighty-two-foot second stage takes over, and its cluster of five engines give a one-million-pound thrust. Within a few seconds the escape tower is jettisoned and after about six minutes of flight the Apollo is 100 miles high. At this point the second stage falls away and the fifty-nine-foot third stage, with its 200,000-pound thrust, takes over and gives the Apollo a nudge into orbit around earth.

While Apollo orbits the earth, computers are busy on the ground figuring the precise time and place to restart the Saturn third-stage rocket. Once refired, it drives the Apollo free of the orbit and on its way to the moon at just under 25,000 miles an hour.

The spacecraft is set on a "free return" trajectory, so that if it fails somehow to get into lunar orbit, it can whip around the moon and shoot back to earth.

"Weightless" in Space

AFTER THE FIRST FEW MINUTES, astronauts easily shake off the effects of the g forces and, once in orbit, become weightless. They enter the unearthly world of *zero gravity,* when speed and path exactly counter-balance the pull of gravity. As long as an astronaut "falls freely" through space he weighs nothing, the rocket weighs nothing and everything in the cabin weighs nothing. A spaceship circling the globe travels in a weightless state at its orbital velocity of about 17,500 miles an hour. That is because the horizontal velocity of the ship and the vertical pull of earth's gravity have the effect of cancelling each other out. A spaceship on its way to the moon is continually weightless once it has gone beyond the significant part of the pull of the earth's field of gravitation—and that requires an "escape velocity" of about 25,000 miles an hour.

So it can be seen that weightlessness is the ordinary condition of space travelers. Photographs of men floating in space make it look as if it might be fun. That is not always the case.

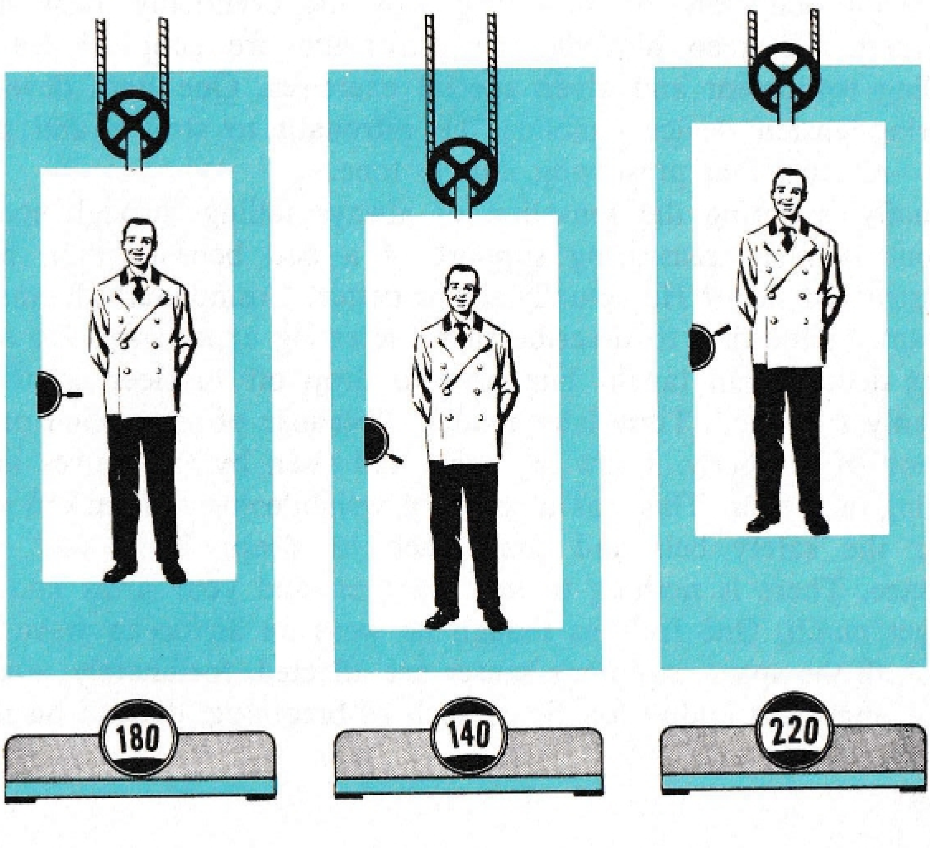
To get an idea of what zero gravity is like—even though for a fleeting moment in these examples—consider the sensation when the car you are in hits a bump and you are "floated" out of your seat for a

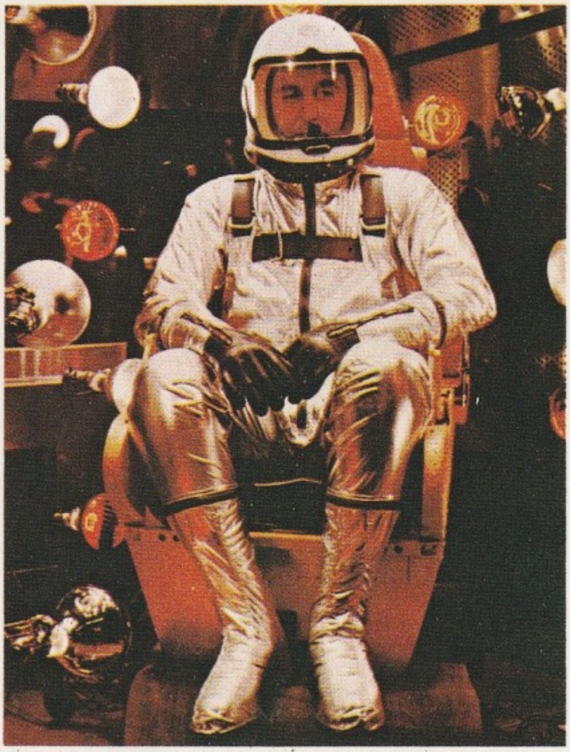
second. Or when you get into an elevator at the fifteenth floor and it drops suddenly, leaving you with your "heart in your mouth" for a moment. Or going over the rise of a roller coaster.

Problems of Control

BECAUSE IT IS NOT ALWAYS COMFORTABLE to move around in the weightless state, the astronauts remain strapped to their couches some of the time. To move around, an astronaut can pad along, grabbing handrails as he moves cautiously about. He has to get used to accepting the ceiling as the floor at times in this freakish world of weightlessness. Try as he will, he won't be able to pour water from one glass to another. Liquids will not stay firmly in a cup. They do not stay together at all but break up into bubbles and float around the cabin. The astronaut must become accustomed to seeing his arm hang out without effort if he puts it out to point a finger, and forgets to

With the elevator stationary, the man's weight is 180 lbs. In first moments of descent, his weight appears to drop by forty lbs.; in first moments of ascent, he seems to be forty lbs. heavier.





6. TESTING A SPACE SUIT

Exhaustive tests are made on each type of space suit. Here an early model, worn by Scott Crossfield, undergoes very high temperatures of the kind which might occur during re-entry.

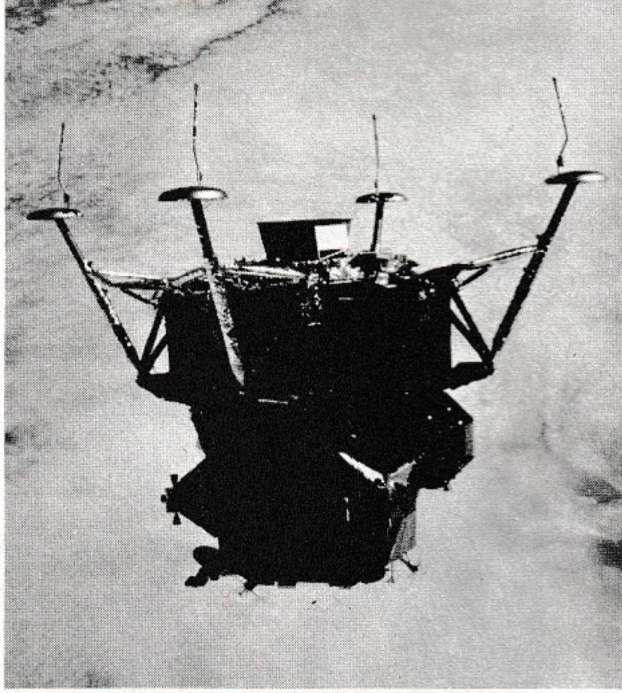
pull it back. Without gravity to resist, his muscles get almost no exercise—a weightless week is equal to two weeks in bed—and this may reduce his body tone on very long trips and eventually make his mind less alert. To keep him fit, the astronauts are supplied with body-building equipment and given special exercises. One item developed is a spring-tension device enabling the astronaut to stretch and pull and push—all aimed at preserving muscle tone.

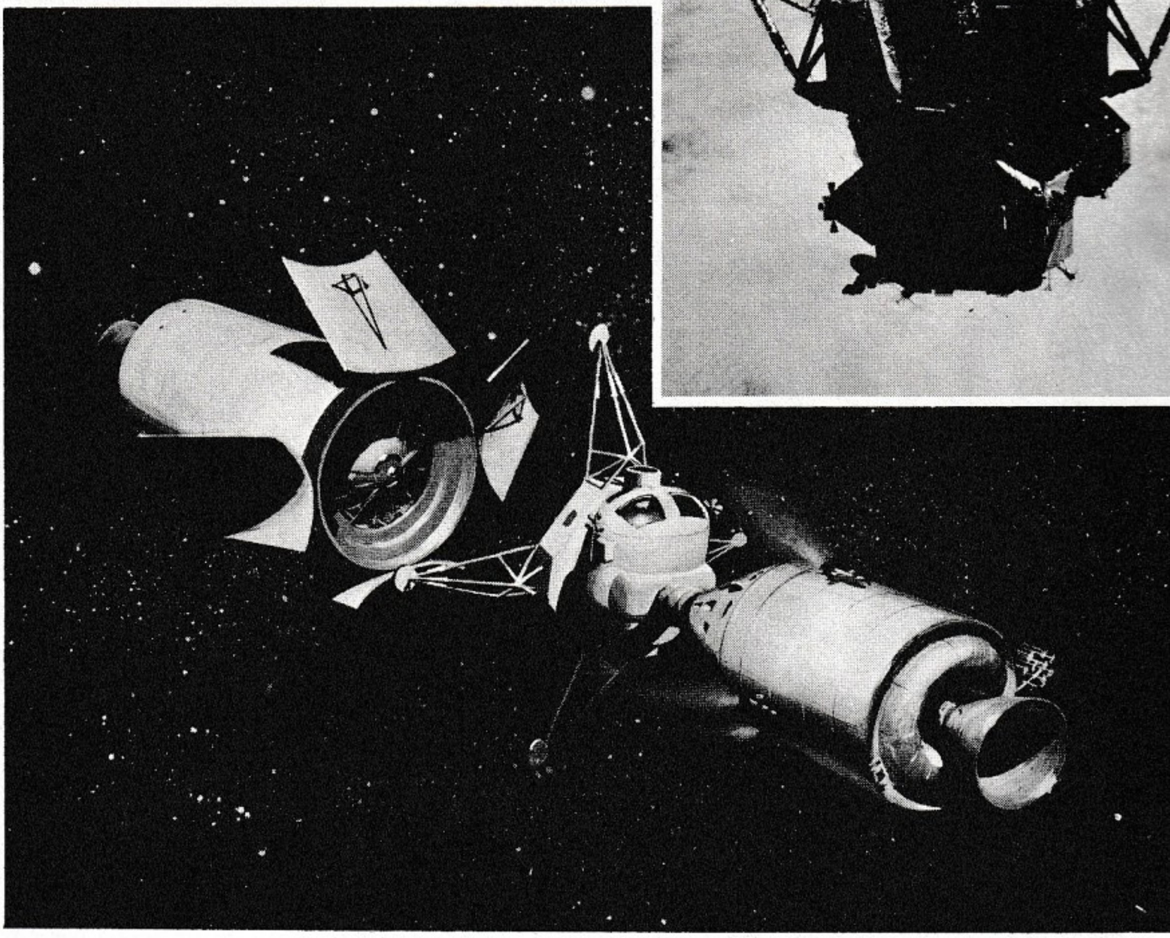
Finally, suffering the sensation of always falling through space, and without familiar, reassuring support of a bed beneath him, how can the astronaut sleep? He actually sleeps better! Cosmonaut Gherman Titov was among the first to describe this interesting experience. He said that Soviet doctors had taught him how to drop off to sleep at will. "But suddenly I awoke," Titov later related, "because of some kind of strange position of my body. I saw my arms had risen by themselves and were hanging in the air. This was a result of weightlessness. I tucked my arms under the safety belt and went back to sleep. It is easy to sleep in space. There is nothing to turn over on and your arms and legs do not get numb. One feels as though he were on an ocean wave."

Not all the space explorer's senses are affected, fortunately, since many of the important bodily functions, such as breathing, depend on muscular

THE APOLLO "MOON SUIT"

The Apollo spacecraft pulls the LM from the Saturn third-stage booster, which is discarded in space, while Apollo continues its journey to the moon. Inset at right shows LM—or "lunar bug"—flying upside down in Apollo 9 mission.





actions that are partially independent of gravity. We inhale by contracting what we call our intercostal muscles and diaphragm and exhale by elastic recoil, and the weight of the chest is a factor helpful to breathing, even in the weightless state.

Turning the LM Around

As THE APOLLO SPACESHIP keeps moving out of the earth's grasp and into the gravitational field of the moon, it is time to bring the Lunar Module, or LM, out of its protective canister. The LM is separated from the rest of the spacecraft by a difficult maneuver and the protective shell is shucked and discarded in space. So is the Saturn third stage. The Apollo Command and Service modules now swing around and insert their nose into the LM's nose. The 22,000-pound-thrust rocket engine in the Apollo's Service Module is exposed. It will furnish the

boost for Apollo's midcourse corrections and, later, provide the power for the return to earth.

The three astronauts, seated in their command cabin between the LM and the Service Module, are in what is called "translunar" flight. They are relaxing more or less in shirt-sleeve comfort and can remove their heavy, pressurized suits. One man at a time can stand up and move around the cabin.

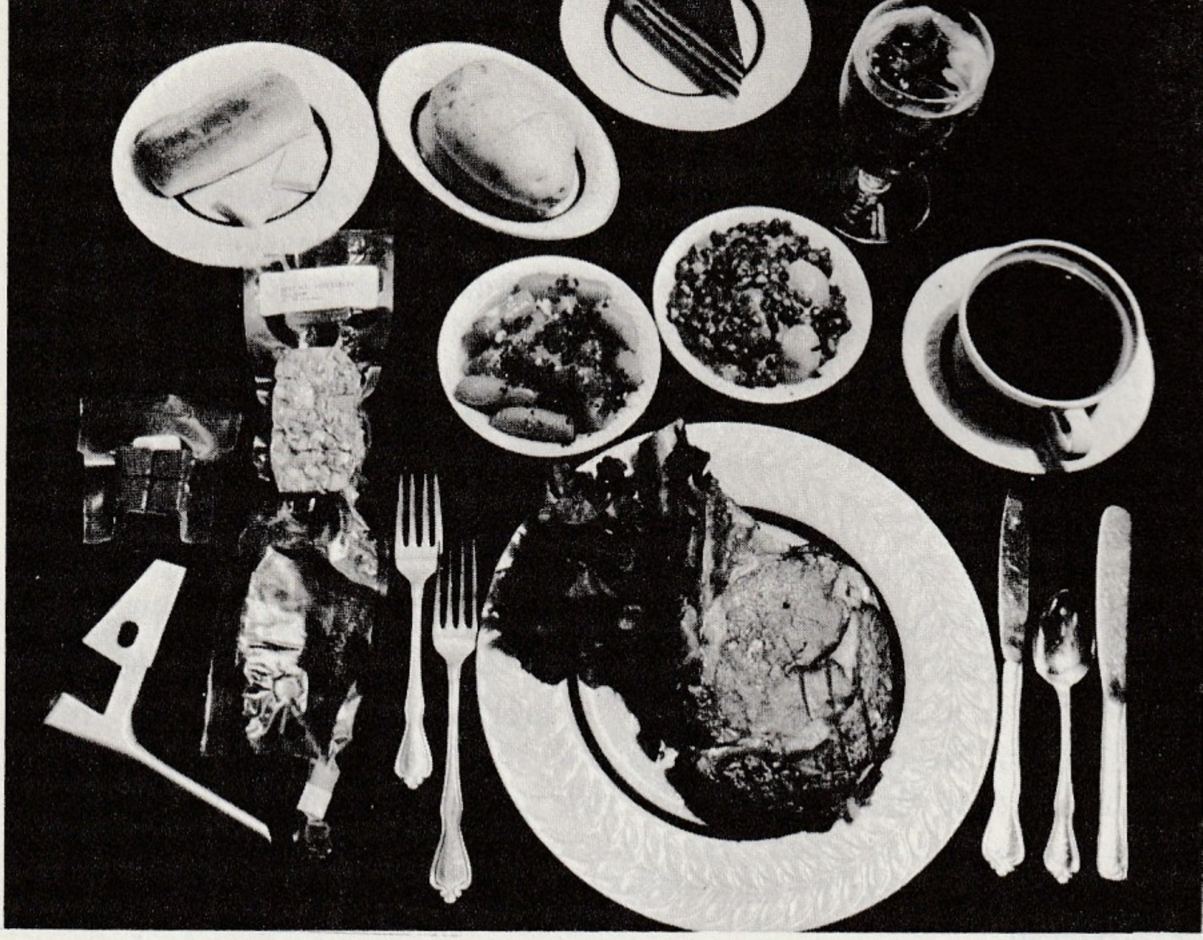
The Spaceman's Suit

SPACEMEN USUALLY ARE PICTURED in suits so bulky that football players seem scantily dressed by comparison. Astronauts complain because the traditional pressure suit not only is archaic, but restricts them from moving about freely and causes discomfort. Former astronaut M. Scott Carpenter called the pressure suit "the greatest handicap we have to manned operations in space." He predicted the day may come when a sort of spray-on space suit, perhaps developed from heat-resistant silicon, will be produced.

The suits worn by the Mercury astronauts actually were two separate full-length garments, together with pressure helmet, leather gloves, two pairs of cotton socks, laced boots and air-intake and -exhaust tubes, a total load of twenty pounds. Yet that suit could not be used in the Gemini program because it was not designed to allow an astronaut to leave his capsule. When Soviet Cosmonaut Leonov took the first walk in space in 1965, he was shielded by a suit that offered special protection from space radiation, from the scorching rays of the sun and from the intolerable cold at 100 miles altitude. America's Gemini astronauts, in duplicating Leonov's feat, had to be provided with similar protection.

The Apollo suit, as it has evolved, is really an integrated series of garments, several separate layers in all. The first layer is a liquid-cooled undergarment circulating cool water through small tubes in direct contact with the skin. The second layer is the pressure garment, or the actual suit assembly. Because the soft pressure garment tends to take a spherical shape when pressurized, a variety of oversized joints are built to provide mobility. Covering the pressure suit is a micrometeoroid-protection garment composed of lightweight materials arranged to provide as much protection as a thin sheet of aluminum. Finally, there is a thermal over-garment composed of many thin layers of super-insulation with a white synthetic fabric as an outer layer.

The Apollo suit weighs almost seventy pounds. The backpack, with



For spacemen, the luscious meal on the plates is dehydrated and trimmed down to that shown in the plastic packages in the left of the picture. A water gun, also shown, is used to reconstitute the food, which the astronauts squeeze out from the packages.

its radio, medical-sensoring devices, oxygen supply and ventilation, weighs another 120 pounds. You end up with a well-protected—and overloaded—space explorer. Cost of the suit: $300,000.

Eating in Space

EATING IN SPACE is a strange experience. One man who seemed to enjoy that experience was Cosmonaut Titov. During his seventeen-orbit flight around the earth he took food several times. In his own words:

"I began to eat. There was no cutlery or napkins on this ship. I reached out to the food containers for a tube of soup purée. On earth it weighed about 150 grams (5.3 ounces); in space it weighed nothing. I squeezed the contents into my mouth, as one does tooth paste onto a brush. My second course was meat and liver paté, washed down with currant juice, also from a tube. Some of the juice drops escaped and hung like berries in front of my face, quivering a little. It was fun watching them float in the air."

For trips around the earth, pastes, juices and bite-sized foods are just

the thing. A typical meal for a moon mission is more appetizing, can be eaten with a spoon and may include pot roast, potato salad, chocolate pudding, brownies and tea. Another is shrimp cocktail, beef and gravy, creamed corn, bread, fruitcake and a citrus drink. About seventy different foods are available for the astronauts' meals.

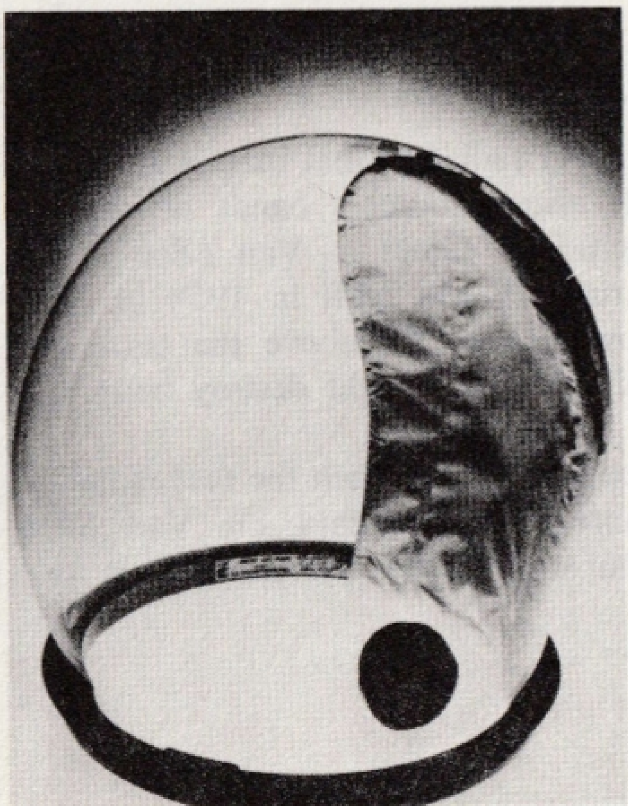
As space exploration expands, the space required for the victuals shrinks. An astronaut can now store in a package no bigger than a shoe box enough food for a week. By a new freeze-dry compression process, NASA has reduced by two-thirds the room needed for food containers. One ten-pound package contains the week's supply of groceries, including 20,000 calories. Running water is available for hot meals and cold drinks.

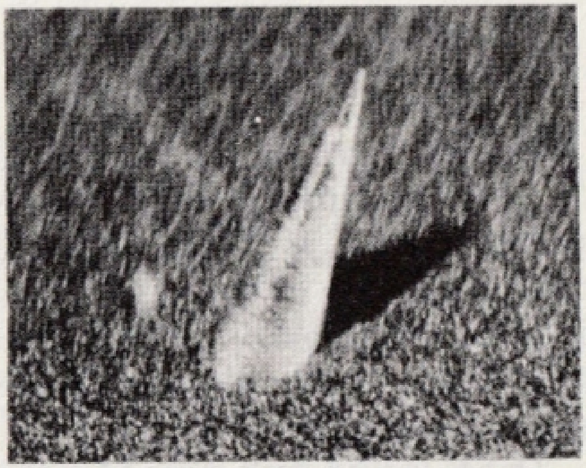
Hazards in Space

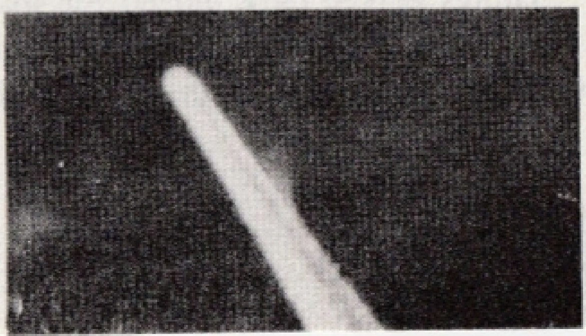
ONE HAZARD awaiting any Apollo crew is a continuous hail of cosmic rays. Another is even more dangerous: radiation from solar flares.

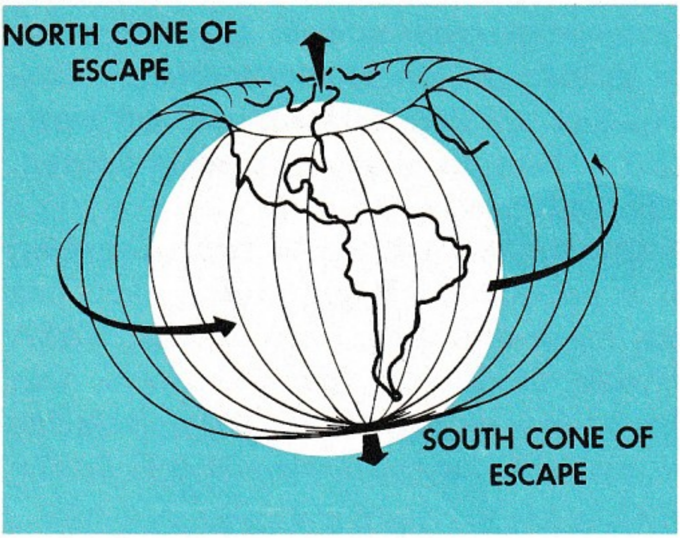
On the surface of the earth, our thick layer of atmosphere acts as a filter to screen out a large proportion of penetrating particles from outer space. Even so, man is bombarded daily with these cosmic rays. The particles are not all alike. They consist of many different kinds, including

Plastic helmets worn to the moon were riddled with the tracks of cosmic rays, highly penetrating particles that can pass completely through a spacecraft. (*Left*) Helmet used by Apollo 8 astronaut Lovell. (*Right*) Silicone rubber replicas of etched cosmic ray tracks from helmets of Apollo 12 astronauts. The tracks are about one-fiftieth of an inch long.









The Van Allen radiation belts encircle the earth except for two cones of escape, one at each polar region. Information from Explorer XII shows that there may be one huge radiation band, now called the magnetosphere, extending 40,000 miles into space.

the positron and many different kinds of mesons. No one knows just where they originate except that it must be somewhere in outer space. To us on earth, they do no particular harm except that they gradually raise the cumulative radiation of the body, which can tolerate a total of only so much. This forms our "background radiation", to which must be added further amounts we absorb in the form of medical X rays and fallout from nuclear explosions.

When man goes beyond the major part of the filtering atmosphere—and remains up long enough—he inevitably will be subjected to a great deal more of this dangerous cosmic radiation. If he were not adequately protected, it would raise his total absorption of harmful radiation to a level that could very well reach disastrous proportions.

The Van Allen Belts

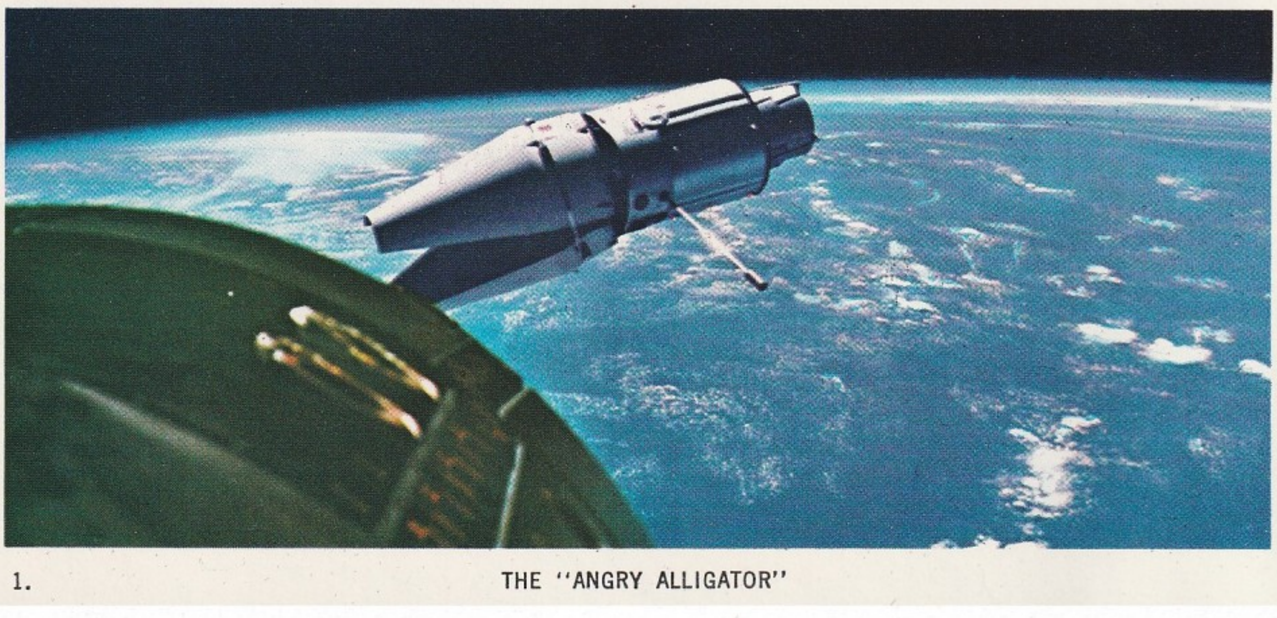
COSMIC RAYS are not the only kind of radiation that man is subjected to on a trip to the moon. He also encounters bands of charged particles known as the Van Allen Belts. Dr. James A. Van Allen of the State University of Iowa, using instruments sent aloft in 1958 in early Pioneer and Explorer rockets, discovered that far above the earth are two radiation belts that are a hazard since they might destroy body and genetic cells.

Things looked dark indeed for space exploration when the first radiation was mapped. But as he gathered more conclusive data, Dr. Van Allen realized that the dangerous radiation was mostly concentrated in two

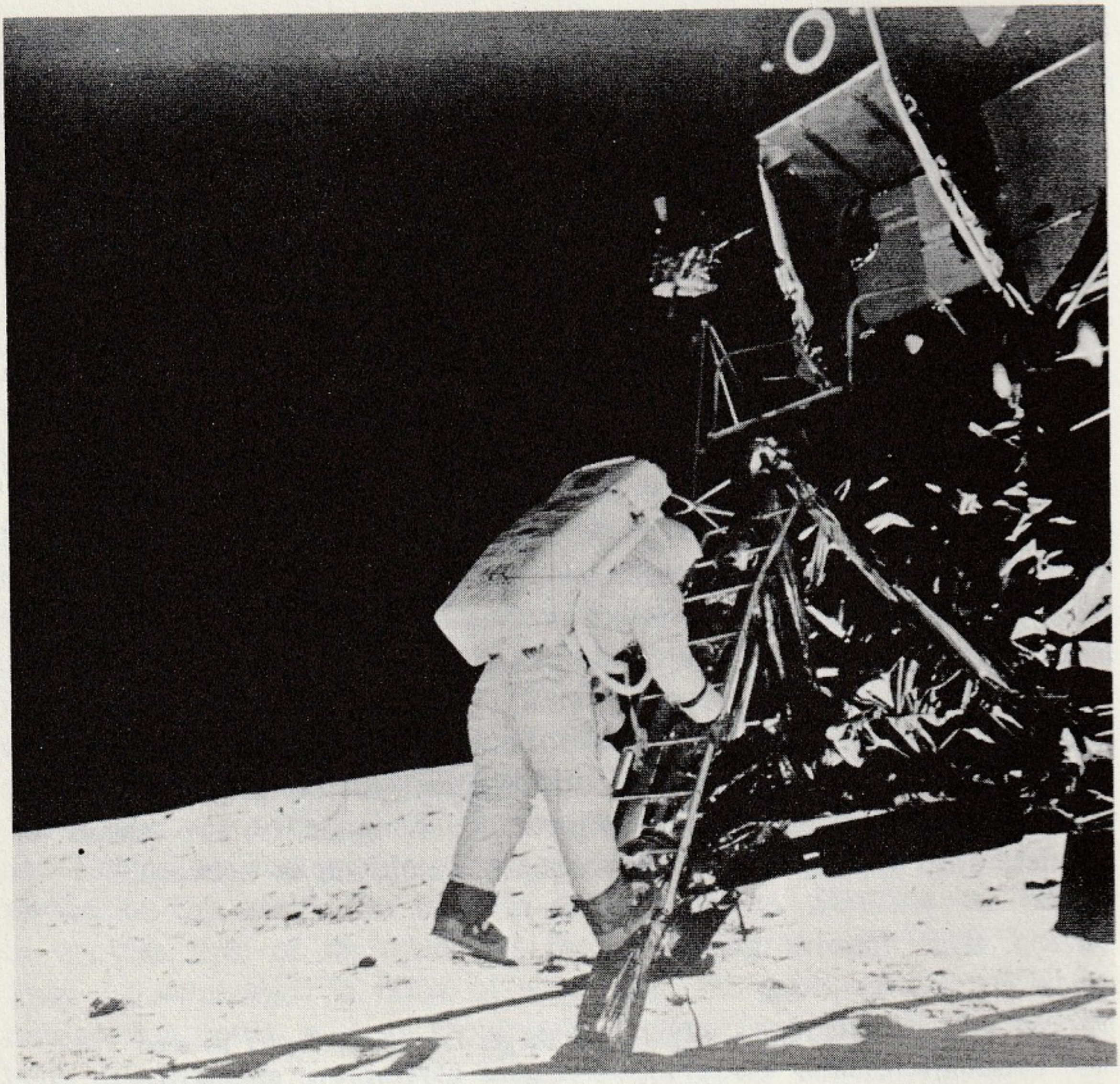
crescent-shaped rings. The inner ring lies from 1,400 to 3,400 miles above the earth's surface. The outer band lies mainly from 8,000 to 12,000 miles out. Although these are the most concentrated zones in the bands, the radiation level starts rising rapidly at about 600 miles. The bands consist of electrically charged particles attracted—as if by so many magnets—to the earth's magnetic field. Scientists want to know more about these particles that move at nearly the speed of light, colliding with each other and with molecules of the very rarified outer fringes of the atmosphere, electrically charging, or ionizing, them.

One of the puzzles now being solved is the exact energy make-up of the particles. They are found to be both relatively heavy cores of hydrogen atoms, that is, protons and lightweight electrons. Scientists also know enough about where they are located so that spacemen can avoid the most dangerous concentrations. The Apollo astronauts, in effect, set a safe course to the moon by making a dash through the charged particles in a well-protected capsule. Their spaceship carries insulation very much like a Thermos or vacuum bottle. Its liner wall consists of honeycombed aluminum sandwiched between two sheets of aluminum alloy. This inner skin is so thin and resilient that a finger touch can make a dimple in it. The outer structure is made of two sheets of stainless steel with a layer of microquartz insulation in between.

Closeup view of the Augmented Target Docking Adapter as seen from Gemini 9 spacecraft. Fiber glass cover yawns around the docking end of the adapter. Thomas Stafford, Gemini 9 command pilot, described the ADTA as an "angry alligator".



1. THE "ANGRY ALLIGATOR"



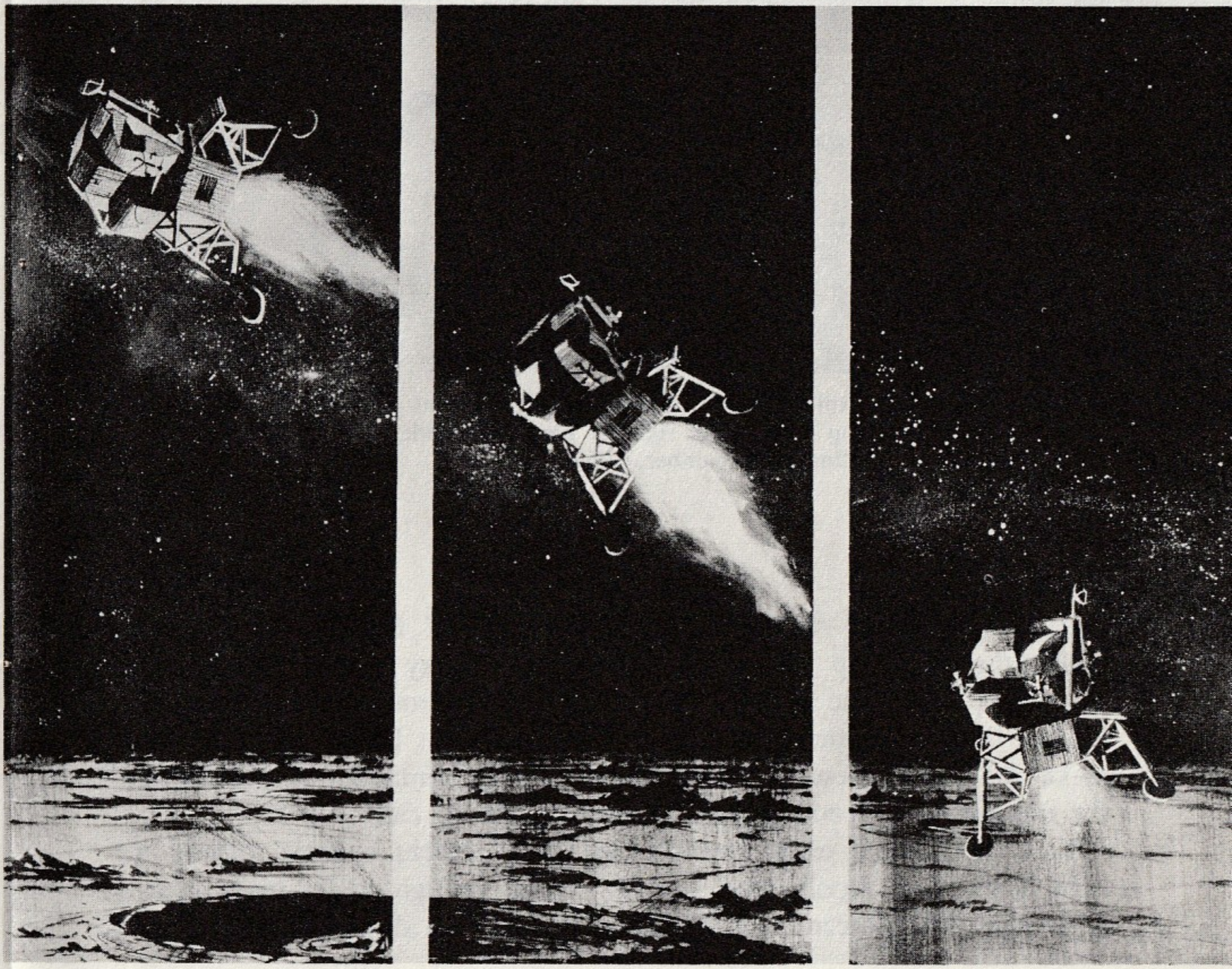
Apollo 11—Astronaut Edwin Aldrin descends to the moon on 20 July, 1969. Photo was taken by Astronaut Neil Armstrong, who was already on the surface.

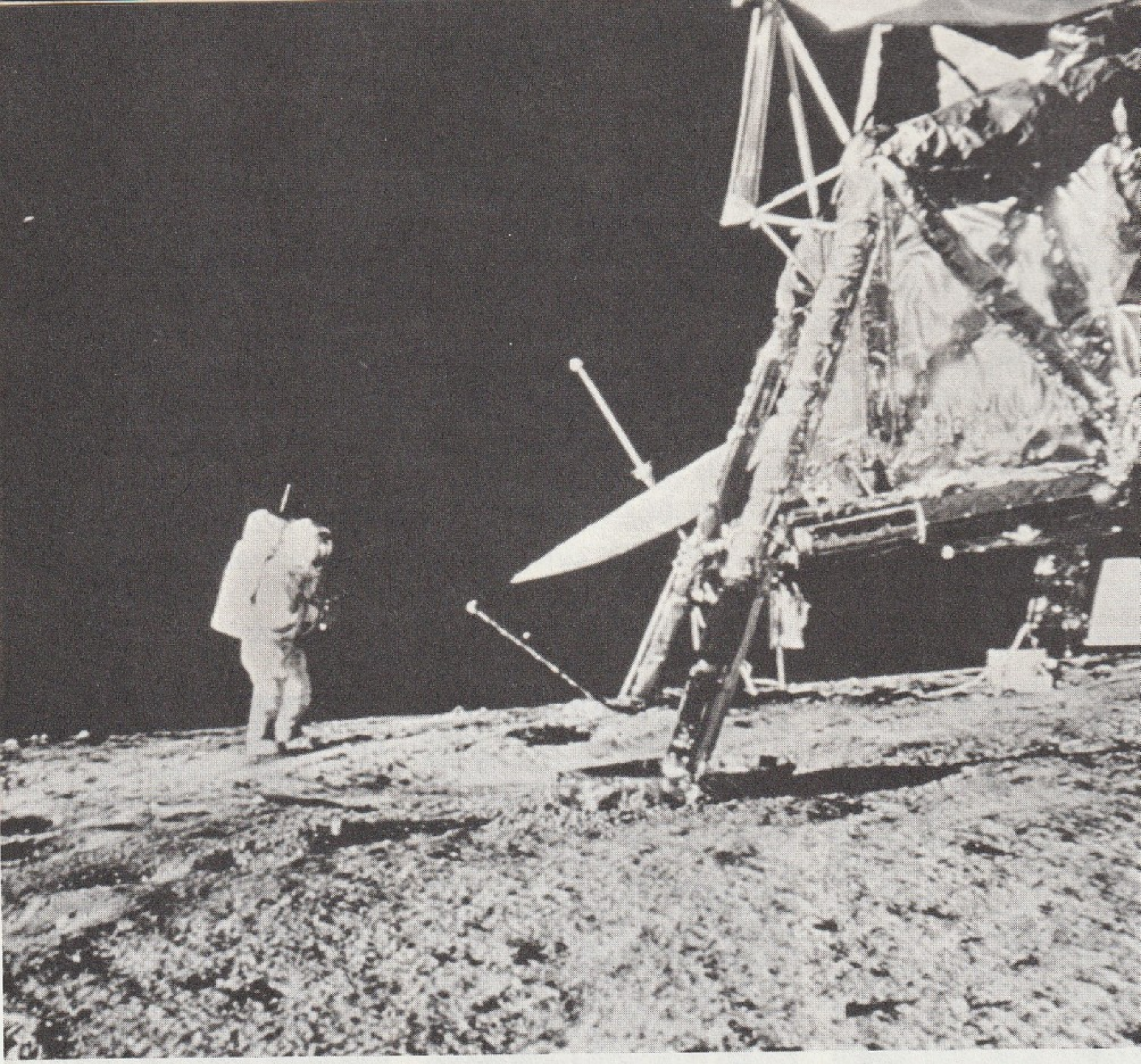
Caution is required in the face of yet another danger. When the sun is at a peak in its eleven-year cycle of activity—sometimes unpredictably more often—it erupts great fountains of charged matter. These are the so-called solar flares. They propel barrages of high ionizing intensity, often increasing by 1,000 times the high energy radiation content above the atmosphere. When these solar storms break, it will be a time for men who make up the space schedules to ground all traffic.

Approaching the Moon

AT THIS POINT in the journey, the Apollo crew is drawing close to the moon. They turn the Apollo around to fire a braking rocket. This slows the craft so it can be captured by the moon's gravity. Once in orbit, say at ninety miles above the lunar surface, Apollo circles at the rate of 3,600 miles an hour—one orbit taking 123 minutes. The astronauts can see the general landing zone, a target that on one mission was 375 miles wide and 1,700 miles long. On Apollo 11, for example, the landing zone was in the Sea of Tranquility.

Descent to a soft landing on the moon by America's Apollo Lunar Module spacecraft is depicted in this panel of illustrations.

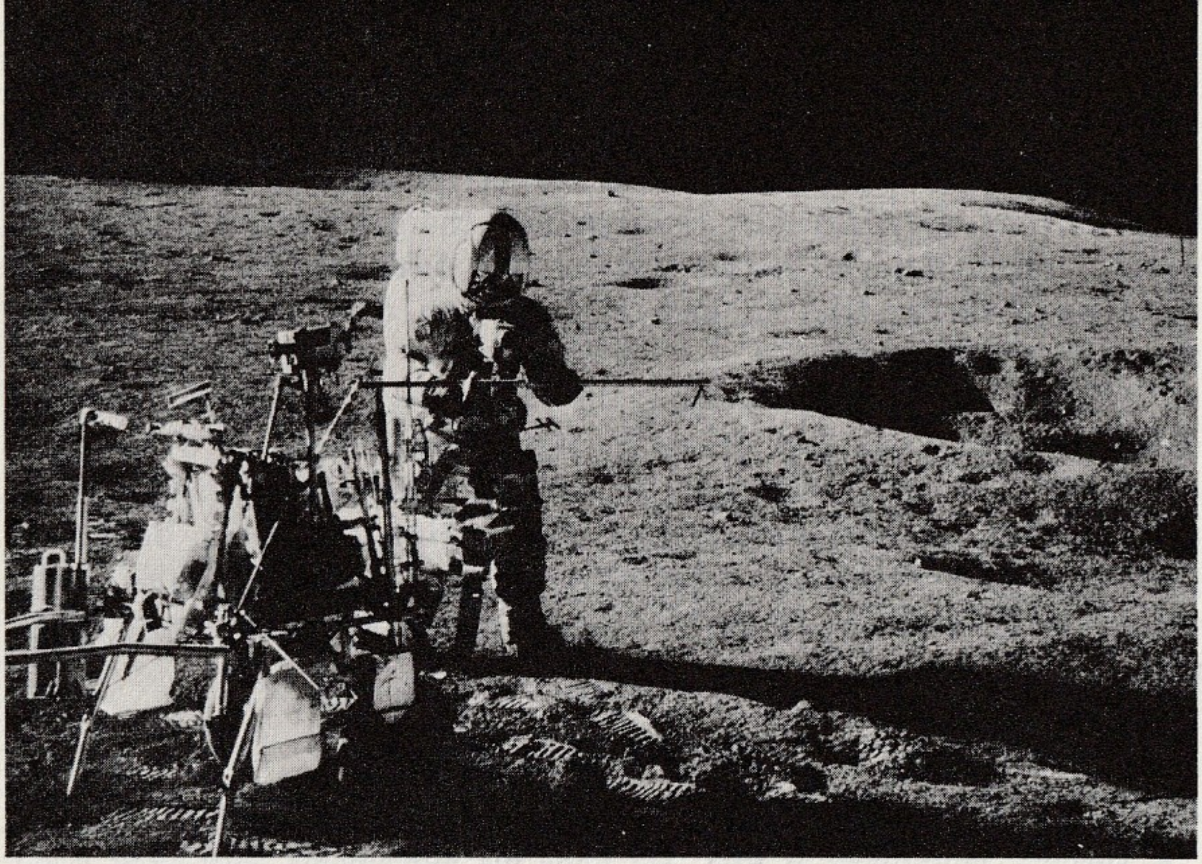




Apollo 12—Exploring on foot. Astronaut Charles Conrad, Jr., did all his exploring well within sight of his lunar lander during the second moon landing in November, 1969.

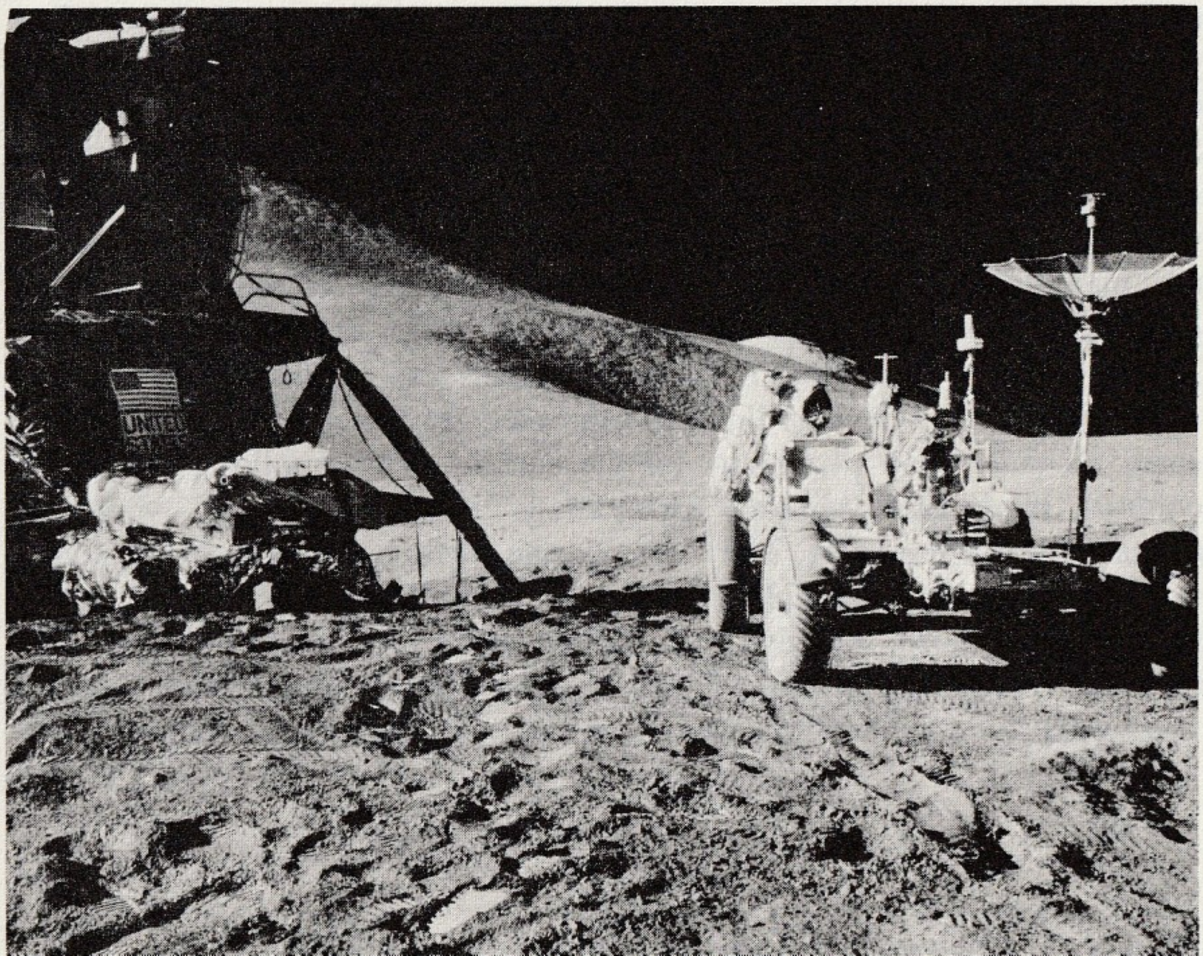
It is now about seventy hours since blast-off from earth. Working under the handicap of weightlessness and bulky pressure suits, two astronauts begin the tedious job of climbing through the narrow link leading them from the Command Module into the LM itself. These two make the actual descent. The third crewman remains in orbit aboard the mother ship, ready to give whatever help he can.

Now the landing team fires up the LM's descent engine, moving the craft away from Apollo and slowing it just enough to let lunar gravity take over. The descent begins. From 50,000 feet down through 10,000



Apollo 14—During the third moon landing (Apollo 13 never reached the moon), Astronaut Alan Shepherd, Jr., made use of a hand-drawn cart to carry tools. Date: February, 1971.

Apollo 15—Astronaut James B. Irwin mounting battery-powered lunar rover that enabled crew on fourth moon landing to cover seventeen miles. Men explored for three days, 31 July through 2 August.



feet, they apply the rocket brakes as needed. About 200 feet above the lunar surface, the astronauts can take full charge. Delicately using the control systems for the descent engine, they further brake the fall, and can even hover to take a quick look through their tiny windows for the best landing spot.

At three feet above the ground, the engines are cut off, the machine drops the final yard, and comes to rest without much of a jolt. The astronauts re-affirm their radio link with the orbiting Command Module and then with the Mission Control Center at Houston, Texas. They prepare the ship for take-off. Eventually, after a rest, the double hatch opens and the ladder goes down. The two astronauts climb down to the surface.

On the Moon

THE COMMAND PILOT is the first man out. He sets both feet on the surface, tentatively at first. He finds his movements easy—but a bit jerky—in an environment where the pull of gravity is only one-sixth that of what he is accustomed to on earth. The astronaut walks around the LM, inspecting it for damage, making certain it is in condition for a later blast-off. By radio, he gives a description of what he sees.

What he and the TV camera see is barren and lonesome, pitted with craters, although relatively smooth where he walks. It is sometimes slippery underfoot, but not so different from what he had expected.

A few minutes later the second astronaut steps down. With both men on the moon, they team up to carry out their duties. These have varied from mission to mission, but all require setting up scientific experiments and collecting lunar samples for return to earth. Nuclear-powered devices, implanted on some flights, radioed data back to earth long after the men had departed. Scientists are looking for answers to age-old questions: What is the moon made of? Is there any evidence of life? Is the moon a dead body? How and when was it formed?

On Apollo 11—the first landing—the men stayed close to the LM and spent no more than two hours on the surface. The Apollo 15 crew, by contrast, made three separate explorations in a "lunar rover"—covering a total of seventeen miles. They were on the surface almost eighteen hours.

After the work is completed, the men settle inside for a meal and a few hours of sleep. Finally, well rested, their work on the moon done, they are ready for a critical test—blast-off from the surface, rendezvous with the mother ship, and then the welcome voyage home.

Blast-off from the Moon

AS THE MOTHER SHIP comes over the moon's horizon and approaches directly overhead, the LM's ascent engine is ignited. The lower portion of the craft, housing the descent rocket, serves as the launch pad and is left behind on the moon. The ascent engine, with 3,500 pounds of thrust, sends the LM off on a curving course to rendezvous with the Command Module. The rendezvous and link-up technique was first perfected by Gemini astronauts. Finally, the two moon-landers crawl back into the Command Module and cut the LM adrift, to be abandoned in space, or to crash on the moon.

Once again Apollo fires up its service rocket, which kicks the spacecraft out of its lunar orbit and starts it on its homeward journey. Drawn by earth's gravity, Apollo picks up speed rapidly until it is streaking in at 36,000 feet a second. After the last correction in its trajectory, Apollo cuts loose the Service Module.

Fiery Re-entry

COMING BACK TO EARTH is tougher than escaping from it. If being rocketed off a launch pad at Cape Kennedy is a brutal way to start a journey, think of what it means to come blasting back at 25,000 miles an hour!

The target now is Mother Earth. This photo, with the moon in the foreground and the earth in the distance, was made from Apollo 10.

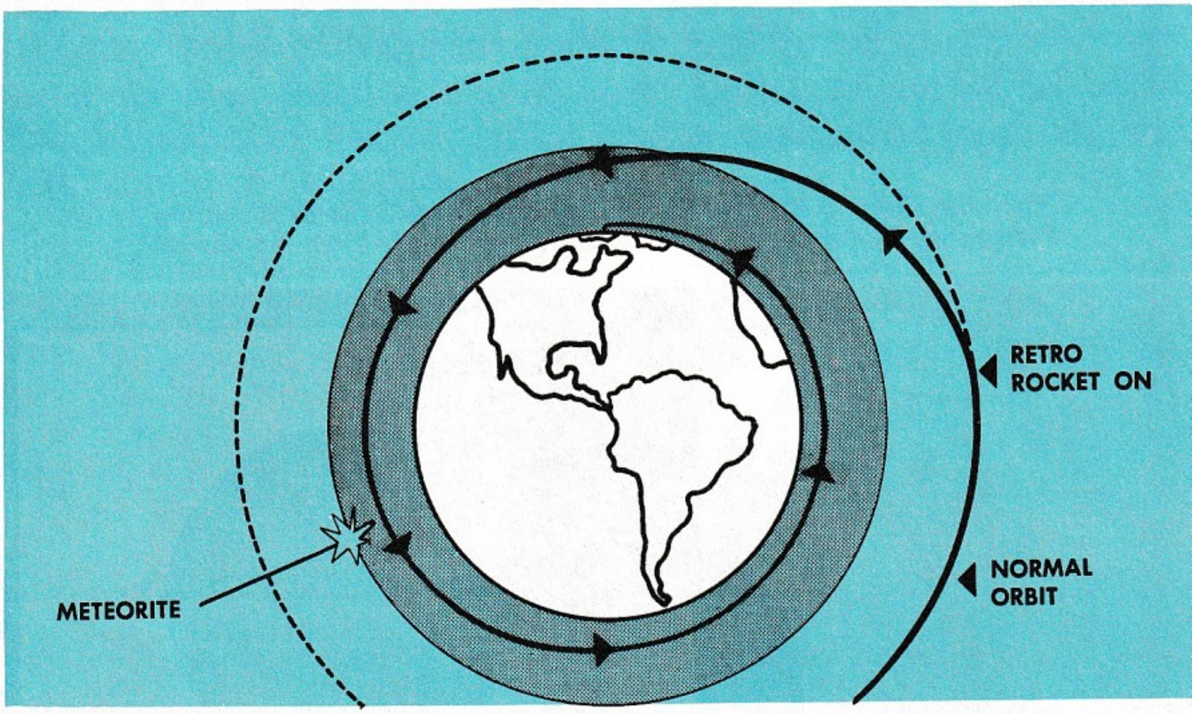
Almost everyone is familiar by now with the retro rockets that slow down our capsules, enabling them to make carefully inclined returns through the atmosphere, and the parachutes that brake the final landings in the ocean.

But orbital flights around the earth—even at 17,500 miles an hour—do not pose the excruciating re-entry problem connected with the return from the moon.

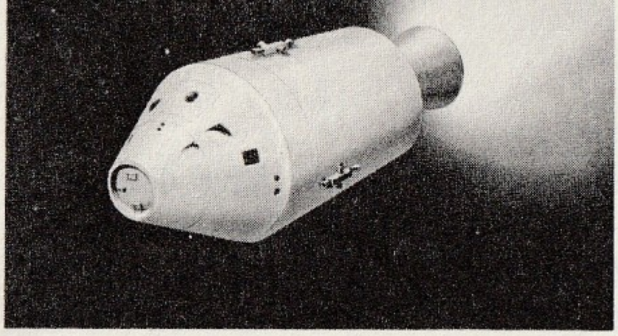
There is a big difference, and that is speed. A speed of 25,000 miles an hour is required to break loose from the earth's gravitational influence and head for outer space. An equal speed is built up by an object being drawn back to earth, when not returning from an orbital path.

Hitting the top of the earth's atmosphere at 25,000 miles an hour is like hitting a stone wall. Potentially crippling high g deceleration forces can be imposed on the crew. In addition, fantastic heat is generated.

A ship returning from the moon is moving at 36,000 feet a second, as we have noted, which means penetrating seven miles of atmosphere each second. A shock wave, forming ahead of the re-entering spaceship, heats the air to many thousands of degrees Fahrenheit, as hot as the visible surface of the sun. The air glows with a bright white light.

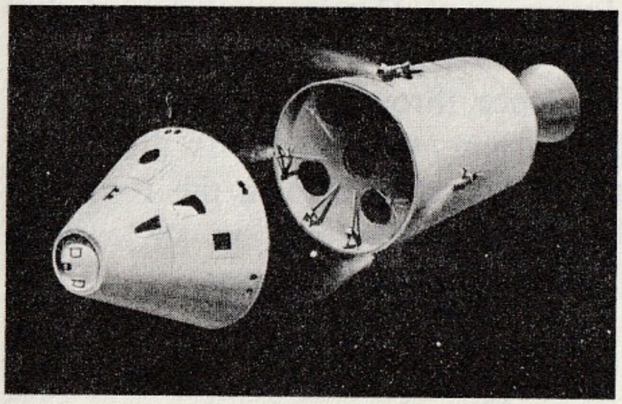


The angle of re-entry of the space capsule must not be too steep, or it will burn up like a meteorite when it meets the earth's atmosphere.



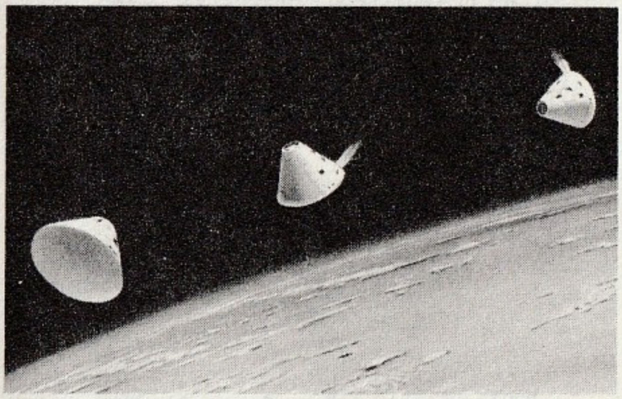
1

APOLLO SERVICE MODULE ENGINE FIRES



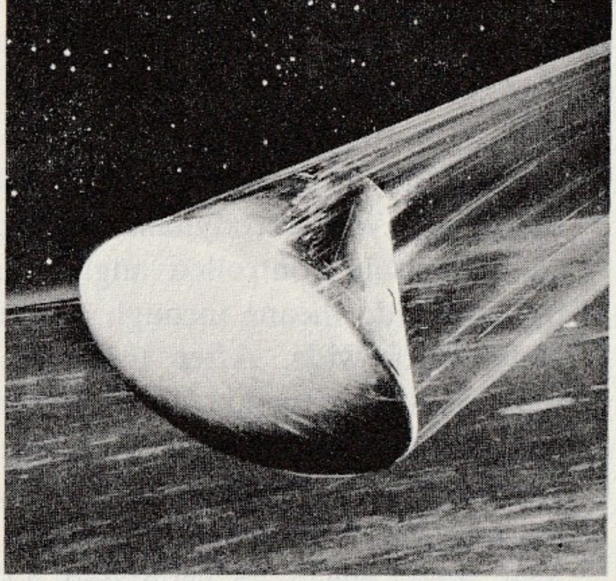
2

APOLLO SERVICE MODULE JETTISONED



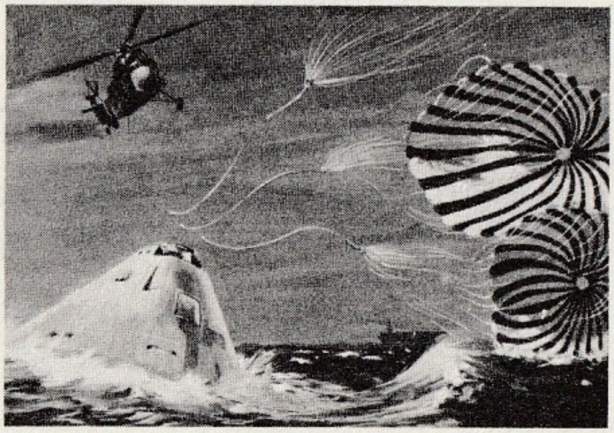
3

APOLLO ORIENTED FOR ENTRY



4

APOLLO HEAT SHIELD GLOWS



5

APOLLO PARACHUTE WATER LANDING

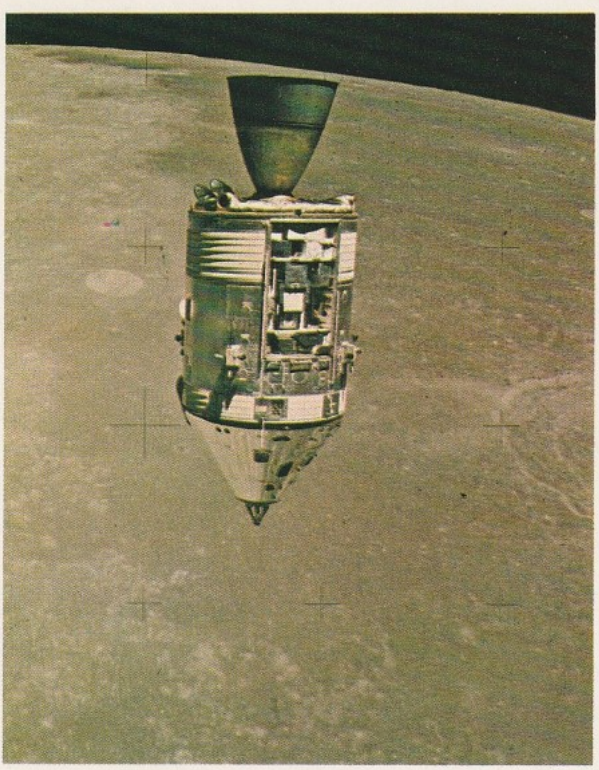
This sequence of drawings, provided by North American Aviation, Inc., prime contractor for the Apollo spaceship, illustrates the final leg of the journey home from the moon.

Photo 1. The LM has been abandoned in space and all three astronauts, now back aboard the Apollo Command and Service Modules, head for earth.
Photo 2. Prior to re-entry into the earth's atmosphere, the Service Module is detached and left to burn up when it hits the top of the atmosphere. Apollo continues on its course.
Photo 3. The Command Pilot now orients the Command Module so the base heat shield takes the brunt of the friction heat.
Photo 4. The Command Module's ablative heat shield glows as the craft re-enters the earth's atmosphere.
Photo 5. The splashdown of the Command Module is followed by release of the parachutes and recovery operations. The journey is over.

What has been done to help the astronauts? Engineers have designed the Apollo with aerodynamic lift so it can enter the tip of the atmosphere at a precisely controlled angle, easing the shock. The course is steered by automatic means through a re-entry "corridor" with an opening about forty miles wide. After that, the astronauts' lives and the success of their mission depends on a special, blunt heat shield and its ability to absorb the fiery heat as Apollo plunges back to earth. At this point, Apollo is four times as hot as the Mercury and Gemini capsules, and its speed is fifty per cent greater. Temperatures on the surface of the heat shield reach an estimated 5,000°F. Once through that ordeal, and with the help of an automatic guidance system, the astronauts fire the craft's maneuvering rockets to "zero in" on a landing area in the Pacific Ocean. At 25,000 feet the first of the parachutes blossoms out to lower the spacecraft gently to a water landing. The voyage soon is over.

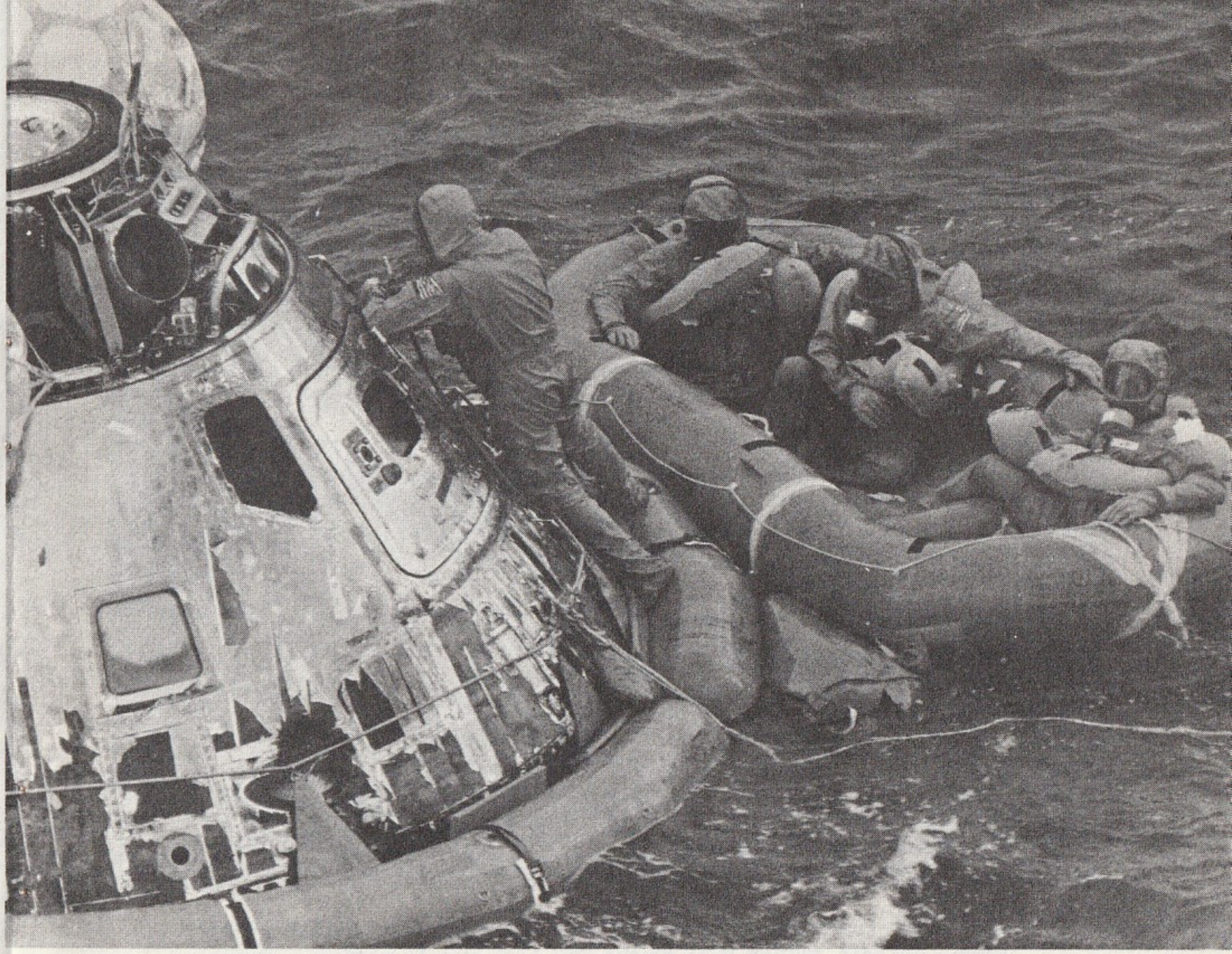
The Challenges Ahead

WITH THE FLIGHT OF APOLLO 17, the U.S. moon-landing program reaches its end, cut short by lack of government funds. It will be



8. PREPARING FOR RENDEZVOUS

This picture taken from the Falcon as it bore two of the Apollo 15 astronauts back from the moon for rendezvous shows Endeavour being flown by Maj. Alfred M. Worden.

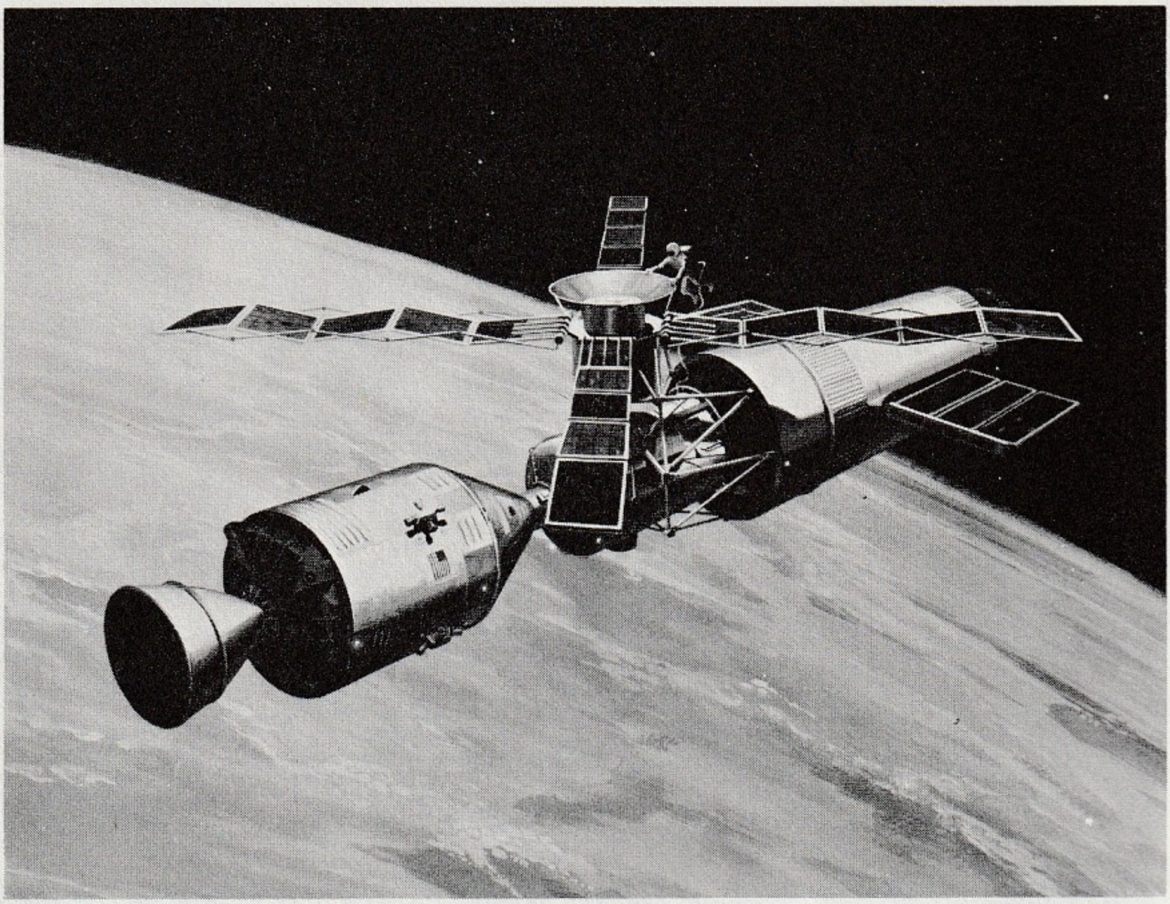


Astronauts Neil A. Armstrong, Michael Collins and Edwin E. Aldrin, Jr., in life raft, await helicopter pickup after return from moon trip on 24 July, 1969. They are wearing biological isolation garments.

a decade, probably more, before Americans again journey to the moon. Emphasis for the rest of the 1970s will be on exploration closer to earth.

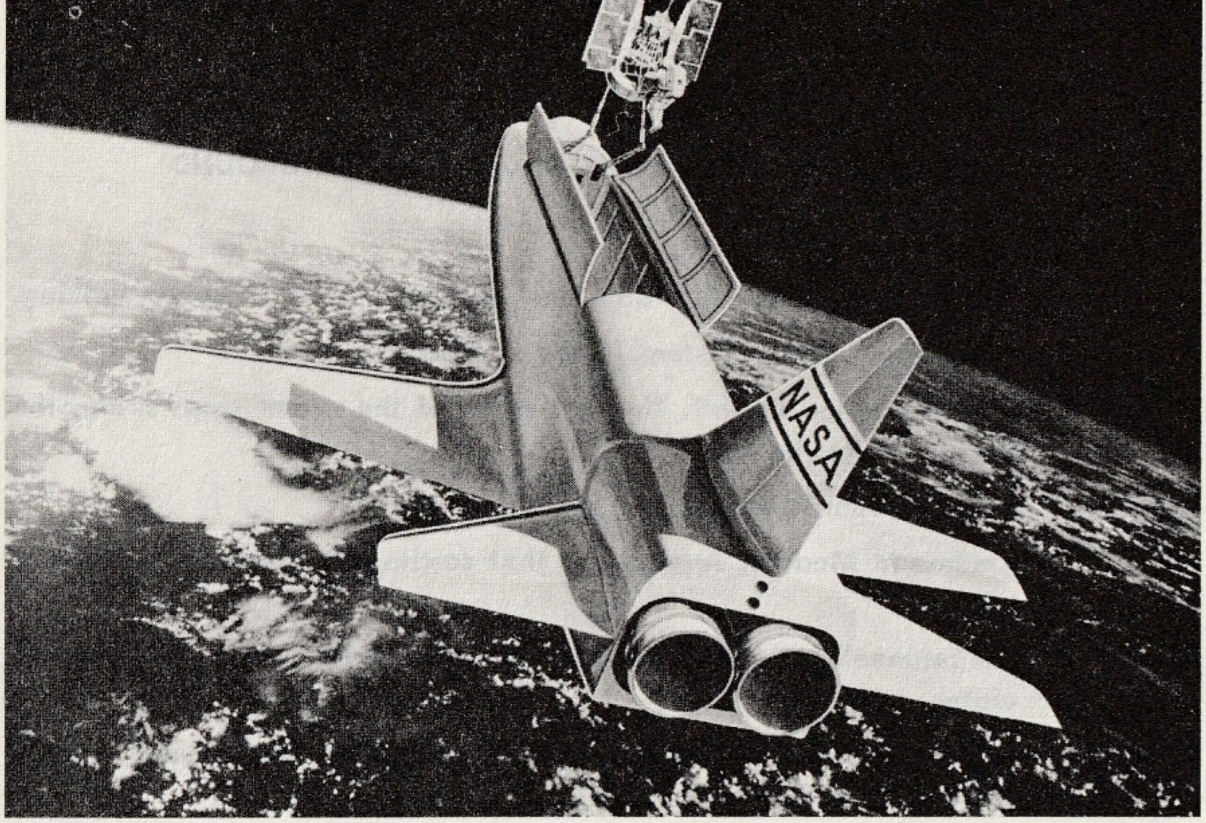
One new project that we will be hearing more about is Skylab, a three-man laboratory that will take on board relays of astronauts for as long as fifty-six days, while it orbits around earth. That is scheduled to start in 1973. Farther down the road are bigger space stations than Skylab, holding crews of up to twelve men.

There are high hopes, also, for development of space shuttles—rocket ships that will carry men to and from orbit in the manner of an airplane, perform other tasks, and be re-usable as many as 100 times.



An Apollo spaceship is shown docked to earth-orbiting Skylab in this artist's concept. Skylab is to be the first U.S. step in putting a permanent laboratory in space. The Apollo will ferry crews and supplies from earth.

Early plans for building colonies on the moon, or sending men to Mars and Venus, have been laid aside for now. But this much is certain: We have sent men to the moon, and in time we will have the means to conquer nearby planets. We know, in theory, how to send ships out as far as Jupiter, which averages about 400 million miles away. Flight to even the nearest star, however, is still beyond any predictable level of man's skill and knowledge. It seems, in fact, that the challenge that lies ahead in space may never fully be met. Remember, we are inhabitants of one small planet surrounded by stars as far as the eye can see—perhaps many billions of galaxies of stars bigger than our own Milky Way. Still, it is risky to predict what can and cannot be done. Space travel fifteen years ago was science fiction. Fifteen years from now it will be science history, for history is now being made.



Later in the 1970s—enter the space shuttle to ferry men to space platforms, perform many other functions. In this artist's concept, an astronaut is checking out a weather satellite that the orbiter has deployed 500 miles above earth.

Man's Destiny

THESE HAVE BEEN ORDEALS, these early explorations, as most of us have surely concluded by now. But the Apollos of space flight will lead to vast armadas of superb interplanetary ships as certainly as the first feeble planes led to supersonic jets.

In this past decade, space scientists have carried us to the threshold of a New World. What was once a vast sea of unpenetrated ignorance is being explored, and if scientists' efforts contribute also to human welfare in general, then they will feel even more greatly rewarded.

As for our astronauts, and other men of daring, conquering the new element will provide its own satisfaction. They know that millions of years ago our forebears came up from the sea into alien air and on to dry ground in a supreme adventure. They did not know what was ahead. Neither does modern man. He is determined to go because the moon and the stars lure him and mock his insignificance. It will be hazardous—even foolhardy—but being man, he must explore.

"SPACE TALK" BETWEEN ASTRONAUTS AND THE GROUND

AMU	Astronaut Maneuvering Unit, the backpack used in space-walking.
ACS	Automatic Control System in the spacecraft.
BECO	Booster Engine Cut-off. The first stage of the rocket stops firing, the second stage ignites.
CAP COM	Capsule Communication on ground.
CM	Command Module, Apollo unit that carries astronauts to moon anc back.
ECS	Environmental Control System. Provides basics such as oxygen water.
ELSS	Extra-vehicular Life Support System, chestpack worn during space-walking.
EVA	Extra-vehicular Activity, an astronaut's operation outside the space-craft.
FPS	Feet Per Second, reported as spaceship closes with target durin rendezvous.
GET	Ground Elapsed Time, time since blast-off.
HIGH-Q	Point in flight in which greatest aerodynamic forces are exerted o the spacecraft.
LM	Lunar Module, the vehicle that actually lands on the moon.
LOS	Loss of Signal, between tracking stations and spacecraft.
LOX	Liquid Oxygen, used as the oxidizer in the ECS.
MCC	Mission Control Center, Houston.
OAMS	Orbital Attitude Maneuvering System, small rockets used to chang the position of the spacecraft while in orbit.
PPS	Primary Propulsion System.
RCS	Re-entry Control System, small rockets used to get the spacecra in the proper attitude for re-entry.
SECO	Second Stage Engine Cut-off.
SPS	Service Propulsion System, the main engine of the Service Module
S/C	Spacecraft.
T-TIME	Scheduled take-off time of a rocket. T minus two minutes means tw minutes before launching.

SCIENCE SERVICE

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